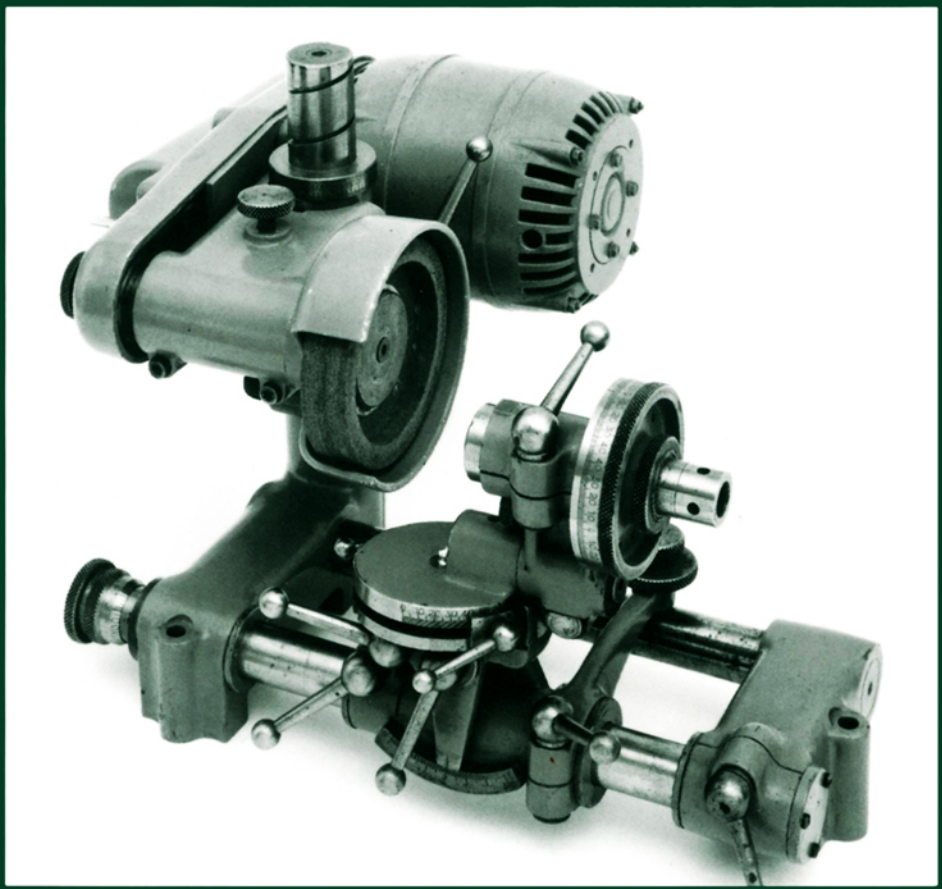
THE 'QUORN'

Universal Tool and Cutter Grinder



Professor
D H Chaddock

THE 'QUORN'

Universal Tool and Cutter Grinder

D H Chaddock

THE QUORN

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The Quorn
Tool and Cutter Grinder

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C.B.E. M.Sc. C.Eng. F.I.Mech.E

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WARNING

Since this book was first published, the Health and Safety at Work Act (1974) has been introduced in the UK. Similar legislation has been introduced in other countries. Such legislation has led to much greater emphasis on safety in workshops which has extended to many leisure activities. Neither the methods nor materials described in this publication have been tested to today's standard and consequently are not endorsed by the publishers. The reader, in pursuing construction and operation of any project, must exercise great care at all times and must accept that safety is their responsibility.

ADDENDUM

Shortly after this book was originally printed Professor Chaddock modified the construction of the rotating base item 29. The change was necessitated due to the difficulty being experienced by some constructors in machining this component from the steel casting originally suggested. A fabrication similar dimensionally to the casting was introduced. It has not been possible to incorporate the modification in this reprint, however, all workshop drawings, materials and castings kits supplied by M.E.S. detail the modification.

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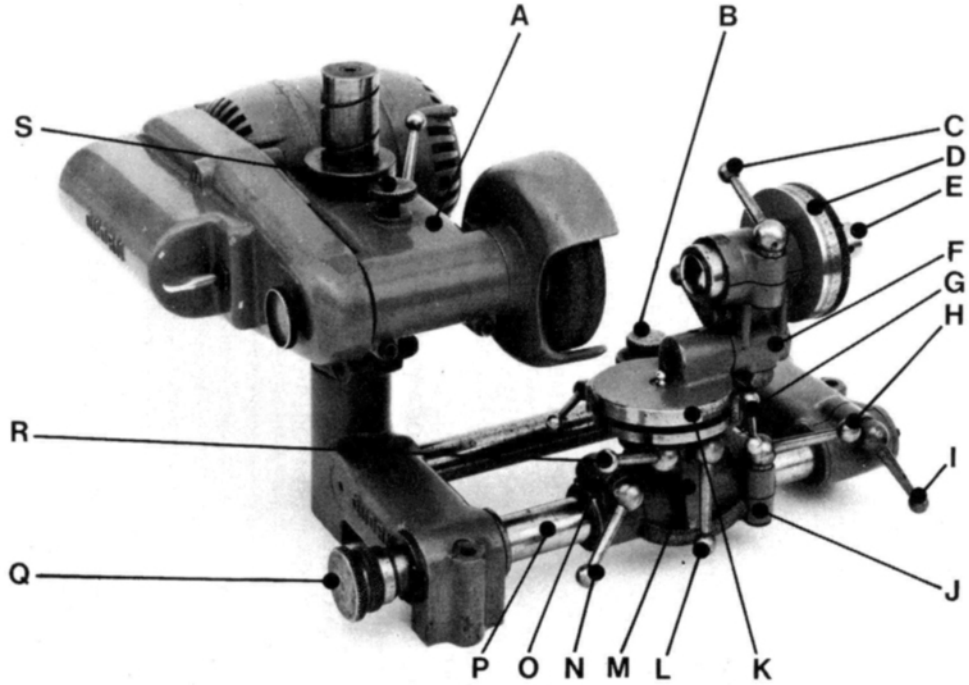


THE "QUORN" TOOL AND CUTTER GRINDER

A-Wheelhead. B-Rocking lever adjustment screw. C-Mandrel lock. D-Index ring. E-Mandrel. F-Tool holder. G-Rotating base stops. H-Rocking lever lock. I-Front bar lock. J-Rocking lever. K-Rotating base. L-Tilting bracket lock. M-Tilting bracket. N-Workhead base lock. O-Workhead base. P-Front bar. Q-Front bar micrometer. R-Rotating base lock. S-Wheelhead adjusting screw.
Note wheel guard in position. It has been removed for clarity in subsequent photographs, but should always be in place when grinding.

PART 1 - MAKING THE "QUORN" TOOL AND CUTTER GRINDER

CHAPTER 1

Introduction

Soon after the acquisition of one's first lathe comes the realisation that the beautiful turning tools bought from the shop do not last for ever and that it is essential to have some means of sharpening them. An early exercise for most of us therefore is the construction of a piece of apparatus, of greater or lesser crudity, which may or may not be dignified by the name of a tool grinder. With increasing experience in the use of a lathe, milling cutters begin to make their appearance and in conjunction with a vertical slide, milling becomes part of the regular workshop routine. More advanced workers who acquire a milling machine such as the Dore-Westbury will soon discover that the range of cutters of all sorts that they have bought, made or "acquired" far outnumbers the lathe tools that they possess.

But in all this there is one fundamental snag, seldom mentioned in the glossy literature, and that is that whereas it is perfectly possible with practice to sharpen lathe tools by hand, it is not so with milling cutters. So the beautiful new cutter which does an excellent job on brass or gunmetal is also used for steel. After that brass and gunmetal seem much tougher and the milled surfaces acquire a nasty fraze which requires a good deal of file work to remove. Steel requires more and more force to be applied to the cutter until finally it breaks, a new one is bought and the whole process begins all over again. The answer is of course that end mills, circular saws and milling cutters of all sorts require re-sharpening just as much as lathe or any other cutting tools if they are to be kept in good condition and to do good work.

It was this experience that finally convinced the writer that a cutter grinder was an essential adjunct to the home workshop if effective use was to be made of the Dore-Westbury light vertical milling machine with which it had been recently equipped. Now while there are excellent cutter grinders commercially available they are expensive – more expensive than the average lathe with which a model engineer's workshop is equipped. Furthermore there are also tool grinders – equally desirable but equally expensive. It seemed therefore that there was a need for a machine which would not only sharpen all the cutters normally used with a light milling machine but would also sharpen lathe tools, drills, reamers and taps at precision preset angles. For good measure it should also be simply adaptable to thread and cam grinding

and be capable of being made in a workshop equipped with a 3½ in. lathe, with some help perhaps in light milling carried out in the lathe or on a milling machine.

Such was the specification of the QUORN Universal Tool and Cutter Grinder. An interesting design exercise resulted in the construction of a prototype machine, shown in the frontispiece.

At a later stage the wheelhead was re-designed to incorporate an end-mounted motor, wheel and belt guards, the latter also enclosing the motor capacitor and the starting and reversing switch. This version of the machine, known as the Mk II and shown in Fig. 1, is functionally interchangeable with Mk I and both will be described in detail in this book. Of the two the Mk II is certainly the neater and in the writer's opinion the better looking. On the other hand the Mk I is the more versatile in that it will accept a wider range of suitable motors; the Mk II is designed for one specific motor only and, subject to not exceeding a safe wheel speed, a wider range of pulley ratios.

The machine is designed around the use of three bars of precision ground round mild steel connected together by two iron castings which combine to give the machine strength, accuracy, rigidity, and freedom from distortion on a three-point support.

The vertical column at the rear carries the WHEELHEAD which is universally adjustable for height and horizontal angle and which, after it has been clamped to the vertical column, can be fine adjusted by micrometer screws over a vertical height of 1 in. The wheelhead is bored to receive a standard 1⅜ in. diam. grinding spindle quill at the front, and at the rear carries a self-contained fractional horsepower electric motor. The complete wheelhead is reversible on the column to enable the side or periphery of the grinding wheels to be presented to the work in the most convenient position.

The REAR HORIZONTAL BAR connecting the two end castings and the vertical column are all permanently bonded together with Loctite. The rear horizontal bar also acts as a datum face for the workhead both in making fine adjustments and as the rear shear when the workhead is traversed.

The FRONT HORIZONTAL BAR carrying the workhead can be rocked to traverse work across the face of the grinding wheel and precision adjusted by micrometer screw and antibacklash spring longitudinally over a range of ½ inch.

The WORKHEAD BASE can be clamped in any position to the front horizontal bar and its angular position set by the ROCKING LEVER, which not only provides an accurate positive stop when the workhead is rocked, but also enables it to be precision adjusted over a range of ½ in. at the mandrel centre line, before the front bar is positively locked. The workhead base carries the TILTING BRACKET, which is adjustable by a pointer reading against a graduated scale over a range of 30 deg. either side of vertical. It enables accurate side and front rake to be given to both sharp-cornered and radiused tools and cutters. Used in conjunction with the swinging headstock, radiused tools with compound geometry, i.e. 7 deg. side rake, 5 deg. front rake, can be ground in a single continuous pass.

The tilting bracket supports the calibrated ROTATING BASE, which has full 360 deg. rotation. It can be freely rotated between ADJUSTABLE STOPS

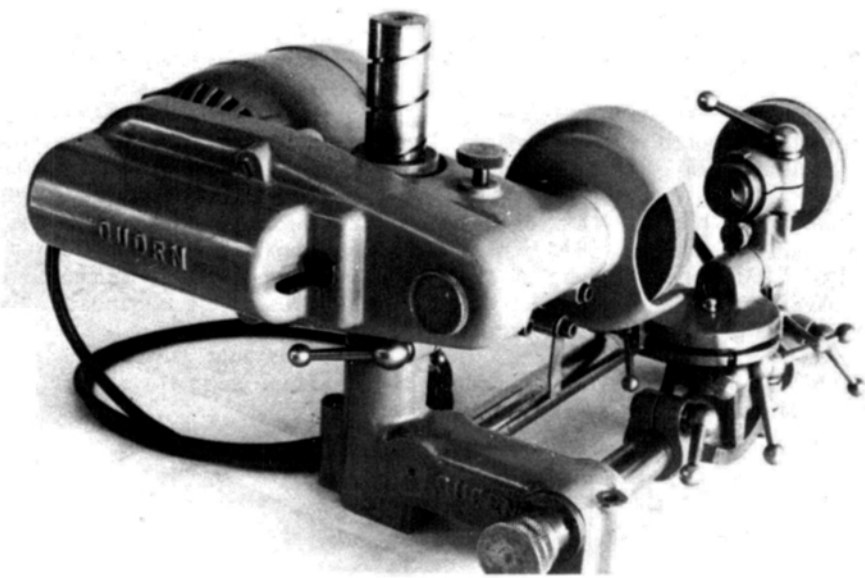


Fig. 1. The Mk.II Quorn.

for radiusing or locked at any pre-set angle for grinding taper and angular cutters and tool faces.

The rotating base supports the SWINGING HEADSTOCK which, by displacing the centre line of the mandrel from the centre line of the rotating base, enables tools and cutters to be corner radiused as well as ball noses to be ground. A removable SETTING PIN enables the two axes and the work to be brought into any desired relationship with one another.

A unique feature of the QUORN Tool Cutter and Grinder is the TRAVERSING MANDREL. By using HOBS of suitable pitch the numbers of start of thread, spiral fluted end mills and slot drills down to $^{1}/_{16}$ in. dia. or less can be accurately and reliably ground and backed off without resetting. The hob engages an adjustable GUIDE PIN and STOP BAR, which enable the flutes on the cutter to be brought into accurate relationship to the grinding wheel. By using fluted hobs, change wheels etc. as temporary division plates, a wide range of side and face cutters, form cutters, circular saws and shell mills may be gulleted, ground and backed-off at a single setting. By using hobs of suitable pitch, e.g. 20 T.P.I., threads can be ground on plain shank cutters to make them usable in screw shank collets such as the Clarkson AUTOLOCK. For larger cutters a TOOTH REST can be used which is attached to the vertical column, is universally adjustable for height and position and can be set to the face or periphery of wheels of any diameter. It can be used inverted if, in certain operations, this gives a better view of the work.

By replacing the headstock spigot by a BAR BED and TAILSTOCK, long reamers, taps and cutters can be ground

between centres using either the tooth rest or a mandrel hob to index the work. In this case the workhead is not clamped to the horizontal bars but slides upon them as shears. The rotating head enables tapered reamers and die sinking cutters to be ground along their length.

By leaving the headstock free to rock on its spigot and using a RADIAL HOB or MASTER CAM on the mandrel and a FOLLOWER attached to the bar bed, cams can be ground and form cutters relieved.

Finally, by using radial and helical hobs in conjunction, taps and hobs can be thread relieved and fluteless tap forms generated.

By replacing the traversing mandrel by a TOOL HOLDER a wide variety of internal and external lathe tools, square and round shank, can be accurately ground to preset angles for side, front, top and back rake. Accurate radii perfectly blended with straight edges at any angle can be produced on form and screwing tools. Female radii can be ground by using the workhead with a DIAMOND or CRUSHER in the toolhead to trim a suitable grinding wheel to shape and then using it to form-grind the tool.

CHAPTER 2

Making and Assembling the Base

Before commencing to machine the base castings it is desirable to decide upon and obtain the material which will be used for the front and rear horizontal bars and for the vertical column and to use the actual bars themselves, or pieces cut from them, as gauges in machining the castings. Centreless ground round mild steel is ideal and although it can normally be obtained in 13 ft. lengths M.E. suppliers will no doubt be able to lay in a stock of the only three sizes required, namely 5/8 in, 1 in. and 1¼ in. dia. and supply the requisite cut lengths for the machine. Silver steel is of course a perfectly adequate alternative but in these sizes very much more expensive. Failing ground stock of any sort a perfectly satisfactory machine could be assembled from ordinary bright drawn mild steel, particularly if care were taken to select pieces which were free from blemish or damage and they were given a preliminary lapping to correct any irregularity or out of roundness. Only advanced workers with sophisticated workshop facilities would want to contemplate case hardened, nitrided or chill cast bars ground and lapped to size which, however desirable they might be for commercial work, need not concern the amateur. However, case hardened, ground and lapped and chromium plated bar stock is now available although at a considerably higher price than mild steel.

Whichever material is going to be used, therefore, the first step is to prepare the front and rear bars and the vertical column, Fig. 2. The former are very simple, merely 12 in. or 13 in. lengths of 1 in. dia. round stock. For neatness the ends can be faced flat and chamfered by setting one end of the bar to run true in a four-jaw chuck and supporting the far end in a fixed steady. A digression here to mention that many workers when they do this find that even when securely gripped the bar tends to work out of the chuck jaws. The reason that it does so is because the end supported by the fixed steady, even if it appears to be running true, is not in fact truly in line with the lathe mandrel axis. It is the resulting orbital motion which causes the work, as it revolves, to creep out of the chuck. With centred work the tailstock, always assuming that it is true, can be used to check the alignment, but bars cut from stock will at this stage have no centres. The way to check alignment is therefore to mount a dial test indicator on the toolpost and, by moving the lathe saddle back and forth, to adjust the jaws of the fixed steady until there is no movement, back to front, or up and down in the length of the bar. If you can get it to 0.001 in. in 1 ft. both ways you are not doing badly.

The front bar needs a little more attention. At one end it should be faced as flat as possible, without pip or centre-hole

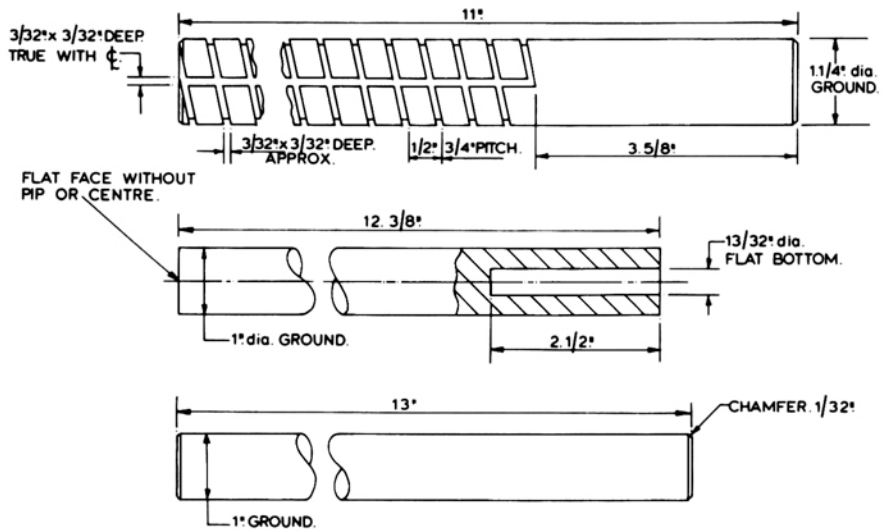


Fig. 2. FRONT, REAR & VERTICAL BARS.

because this face will be the anvil against which the micrometer adjustment screw will work. Posh workers can lap it flat but good clean facing will suffice. At the other end the bar is drilled 2½ in. deep by 13/32 in. dia. to accommodate the anti-backlash spring. No great precision is required here but the hole should be flat bottomed to provide a fair seating for the spring.

The vertical column 1¼ in. dia. by 11 in. long with the ends faced flat and chamfered is also shown in the general arrangement and detail drawing Fig. 2 with a quick start thread, which will terrify most amateurs and many professionals too. Straight away let us say that it is optional; the machine will function perfectly without it. Its only purpose is to provide an easy means of height adjustment and in the event that the wheelhead clamp should be slackened without first taking the weight, to prevent it dropping to the bottom of the column. For those who like a little luxury and are prepared to put in the effort to achieve it, the job can be perfectly well accomplished on a 3½ in. lathe and some notes will be given later as to how it can be done.

Having prepared the three bars, a start can now be made on machining the right and left base castings as shown in Fig. 3, which connect them together and form the basic foundation of the machine. The castings are too large to swing even in the gap of a 3½ in. lathe, although if a larger lathe were available they could be clamped to an angle plate mounted on the faceplate and the holes bored in the time honoured way that "Live Steamers" bore their cylinder blocks.

The base castings can be quite easily mounted on the saddle of the lathe and the cored holes bored to size by a boring bar between centres. This method also has the advantage that by using the cross-slide to traverse the work from

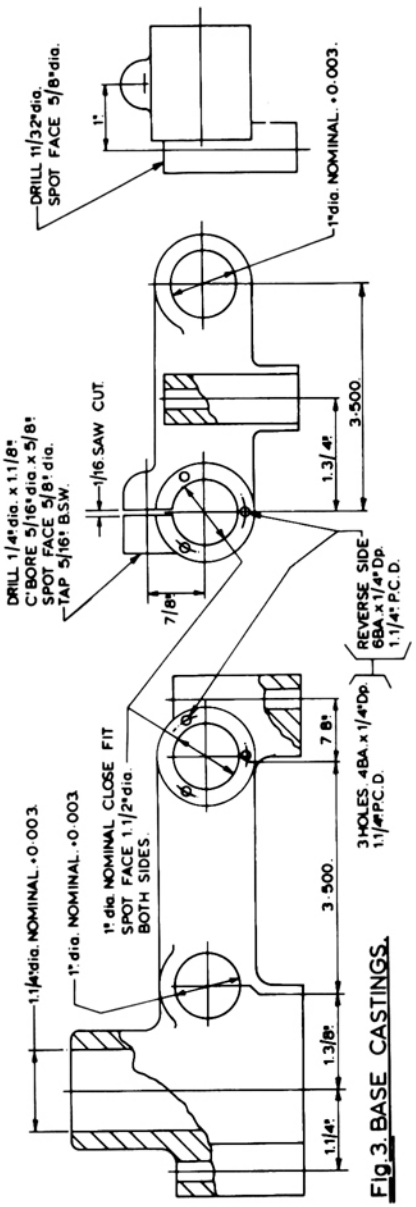


Fig.3. BASE CASTINGS.

one hole to the next not only will the two holes be exactly parallel but the centre distance between them can be made closely the same for the right and left hand castings. Here it is worth commenting on the fact that although the centre distance is shown as 3.500 in., indicating that it should be worked to as closely as possible, the actual distance is relatively unimportant, all that matters is that both ends should be the same. If therefore before boring the first hole and locking the cross-slide in position the feed screw is carefully turned right-handed and the micrometer index set to zero, the second hole can be accurately positioned by turning the feed screw the requisite number of turns – 35 in the case of a 10 t.p.i. screw – and finishing up again turning right-handed until the micrometer index is again at zero. By this method all backlash is eliminated and one can freely go from one hole to the other and back again. This is convenient with a boring bar between centres because setting the cutter bit to bore a given diameter is always a bit of a fiddle and a little bit uncertain until a trial cut has been taken. So both holes can be rough bored in turn with the same boring bar setting.

The rear hole, which is the less critical, can then be opened out until it is a neat sliding fit for the front bar and this setting immediately used to bring the front hole to size. Thereafter a slight tap on the cutter will give the necessary oversize to bore the rear hole with clearance. Moving the work between cuts and putting it back afterwards sounds all wrong, but if one accepts the fact that work can be accurately positioned by the use of feed-screws, if it can be set right the first time it can be re-set equally accurately any number of times thereafter. There is no magic in the first setting. Any of the

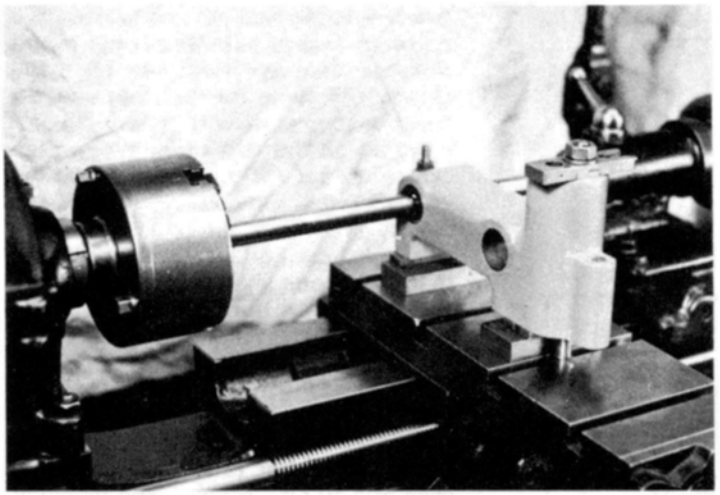


Fig. 4. Machining the horizontal holes.

subsequent settings will be equally as accurate – or inaccurate – but the greatest care need only be exercised on the final setting when the cuts are light. Of course the centre distance will not be 3.500 in. to N.P.L. standards, but as already explained that does not matter if both ends are alike. Some workers, however, may prefer to bolt the two castings together through holes drilled in the side walls and machine them as if they were one. This is perfectly satisfactory and

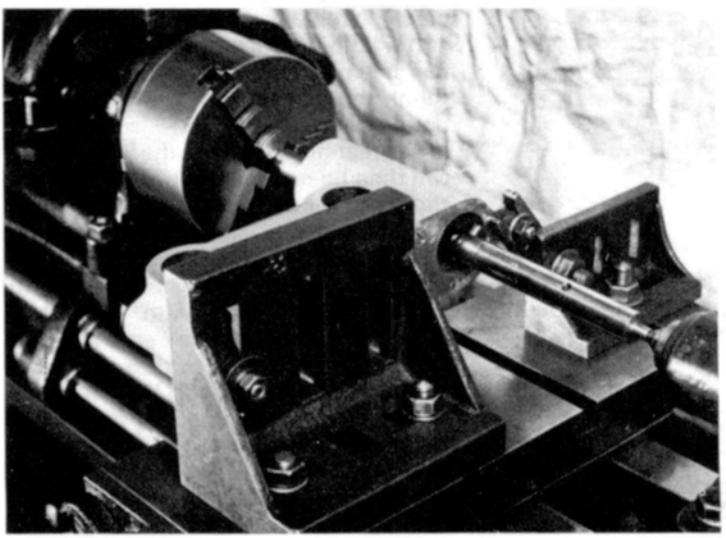


Fig. 5. Machining the vertical hole.

ensures that the centre distances are identical without relying on a "Dead reckoning" setting of the cross-slide. The slave holes can be later plugged or filled when the castings are painted.

The castings need little preparation prior to setting up. The under surface should be dressed with a file until the casting sits fair and without rocking on a flat surface. It is convenient too at this stage to drill the holes for the holding-down bolts, which are not critical, as they come in handy for bolting the casting on the saddle – as in Fig. 4. The holes at the back should be a clearance fit for the fixed bar which is going to be "Loctited" into them. The clearance can be checked by inserting a .003 in. feeler along with the test bar. The front holes should be as neat a fit as possible for the front bar which must slide in them without play. If anything it is better to leave them on the tight side because they can always be lapped out afterwards. This will almost certainly be necessary with the right-hand base casting, the hole in which may tend to close up after the casting is split for the clamp screw.

The 1¼ in. dia. hole for the vertical column can be bored in exactly the same way with the casting bolted to angle plates on the cross-slide. Because the writer does not own an angle plate big enough to span the length of the casting, nor if he did would he be prepared to bore a hole in it big enough to clear the boring bar, he used two angle plates to support each end of the casting. Although the set-up shown in Fig. 5 looks a bit dodgy it worked perfectly. This hole too should be bored a clearance fit for the vertical column. The other operations, drilling, tapping, sawing etc. are conventional and need no comment although as is standard amateur practice the 4 BA drilled and tapped holes are most conveniently spotted off the mating components.

Here it is to be explained that in this design all dimensions are Imperial and threads BSW, BSF, or BA. Owners of suitable screwing tackle can replace them with UN or SI but if this is done the coarse series should be used for threads tapped into cast iron, not the fine.

The front and rear bars should now be tried in both end castings together. The front bar should be a close fit but free to move, the back bar should have appreciable clearance so that the front bar can find its own alignment. If all is well, remove the back bar and thoroughly clean its ends and the holes in which it fits, either with hot strong detergent or preferably with the special cleansing fluid supplied by the makers of Loctite. Don't touch the ends or the holes after they have been cleaned before coating them with Loctite. Reassemble and lay the two bars across a surface plate as in Fig. 6 and leave it thus until the Loctite has hardened. The object of this manoeuvre is to bring the two bars absolutely into the same plane even if there was some residual error in boring the holes in the end castings. After the Loctite has set, it ought to be possible to hold four pieces of cigarette paper between the bars and the surface plate – the toolmaker's traditional test for truth. "Loctiting" the vertical column must be done separately but needs no special precaution. If the end of the column is faced truly square and the job stands upon a surface plate it cannot be other than upright.

Before doing this, however, a decision must be taken as to whether it is to be screwed or not – once it is in it will never come out again. Those therefore who are opting for a plain column can skip the next section – others read on. Firstly

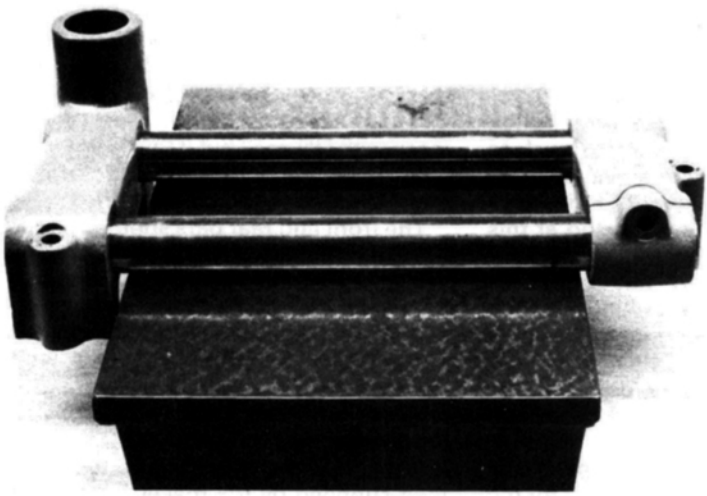


Fig. 6. Assembling the base.

how can you cut a ½ in. pitch thread on a lathe if it is not shown in the screw-cutting table? The answer is easy – if it has an 8 t.p.i. lead screw and will cut 32 t.p.i. it will also cut ½ in. pitch. Just put the change wheels on backwards so that the leadscrew is running 4 times faster than the mandrel. The train the writer used was 40/20. 60/30 with a 50 T idler between the 60 T and the 30 T wheels. But there is no magic in ½ in. pitch, anything between ½ in. and 1 in. will do and it does not matter if it is in fractions. So just put the largest wheels you have on as drivers and the smallest on as driven gears. Lucky owners of lathes with Norton boxes are not so lucky here – the best the Norton box can do is 1:1 and they will have to borrow or improvise some transposing gears. If I owned such a lathe I should fit a 45-50 T bicycle sprocket to the lathe mandrel and a home-made 12 T sprocket to the input shaft of the Norton box. Not ideal perhaps but with chains one can get away with a lot and it would work.

Geared this way the lathe cannot of course be driven from the mandrel even with the back gear in. It must be driven from the leadscrew and although this can be done by hand the feed is rather coarse. One turn of the leadscrew handwheel will rotate the work ¼ of a turn and produce a length of cut of 1 in. on a 1¼ in. dia. bar. Since this is equivalent to a feedscrew of 1 t.p.i. it is rather coarse for a 3/32 in. end mill. For this and similar work the writer has found it well worth while to rig up a worm drive to the leadscrew and many years ago he cut a 14 D.P. worm which meshes with any or all of the lathe change wheels. An additional 50 T wheel was put on the leadscrew stud and the worm engaged with it as shown in Fig. 7.

Having got so far it seemed logical to provide a power feed since this is much kinder to the cutters and produces better work. Now the recommended depth of cut for a slot drill is ½ of the cutter diameter, which for a 3/32 in. dia. cutter is 0.047 in. and so two passes would be

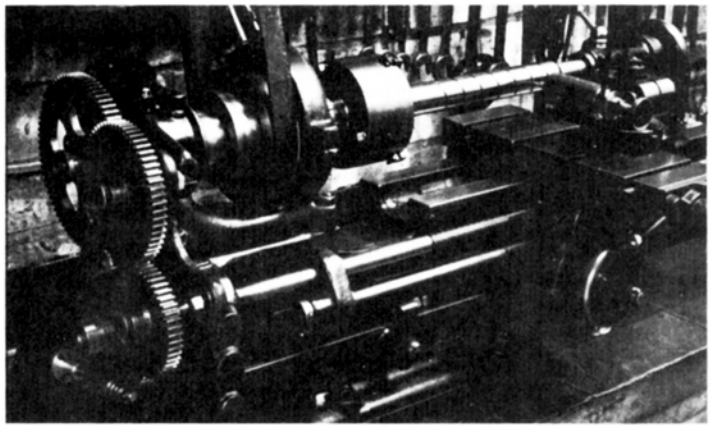


Fig. 7. Change wheels set up for spiralling.

required to produce a slot 3/32 in. deep. Also the recommended speed and feed for a cutter of this size in mild steel is 4278 r.p.m. and 1¼ in. per minute respectively. It was not convenient to drive the cutter at this speed, in fact it was run at 1940 r.p.m. but there is no harm in this provided that the rate of feed is reduced in proportion so that the depth of cut per tooth remains constant. This therefore demanded a feed speed of about ½ in. per minute, that is the work should revolve once in 6 minutes and the total cutting time for each pass of 13 turns should take about 78 minutes – a clear case for automatic feed! Incidentally this simple calculation shows how wrong one could be in guessing the right feed and then attempting to apply it by hand. One or two trials with rough wooden pulleys and lots of plastic belt showed that this could indeed be achieved and the final set-up shown in Fig. 8 worked extremely well. After everything was set up it was only necessary to stand by for over an hour dabbing on cutting oil while the lathe solemnly completed each pass. Why not automate the oil feed? Well, there has to be a limit somewhere!

The milling spindle used in this operation is one that the writer made many years ago and has been used in innumerable milling, drilling and grinding operations. It is very similar to the quill which in due course will be described for use with the Quorn tool and cutter grinder itself. So if you have not a suitable spindle make this up next and discover for yourself what a difference a precision spindle running in pre-loaded bearings can make to seemingly difficult milling operations. I have described this operation at some length to show that with a little ingenuity and some simple figuring to get the numbers right, a seemingly impossible job is not only within the compass of an amateur's workshop but can add considerable interest to his work.

The mechanism for controlling the position of the front bar and therefore the workhead attached to it is shown in Fig. 9. The writer pondered for some time whether the micrometer screw should be on the left hand side, with the anti-backlash spring on right, as shown in the drawing, or whether the opposite

arrangement would be better. The latter certainly gives a positive feed of the work towards the wheel, but the writer decided upon the former arrangement for two reasons. Firstly it seemed more natural to hold the work and the workhead with the right hand and to use the left hand to make adjustments by turning the micrometer screw. Secondly the maximum pressure that can be applied between the work and the wheel is limited to the strength of the anti-backlash spring. This is an obvious advantage in preventing the machine being overloaded or in extreme cases wheels being broken. However, like all good designers the writer has hedged his bet – the parts are completely interchangeable and can be assembled either way round!

Although a 3/8 in. BSF thread is called for on the micrometer screw shown in detail in Fig. 9, this is mainly for convenience in tapping the corresponding female thread in the body with a standard tap. The male thread on the screw itself should be lathe cut, although a die may be used to bring it dead to size to fit the already tapped hole. Actually to make the best of a job like this it is best to truncate the threads. That is to say after tapping the hole pass a Letter 'O' drill through it to clear the crests of the female threads and turn the crests off the male threads on the screw down to a diameter of 0.367 in. This ensures that when a fit is obtained it will be on the flanks of the thread and not just hanging on the crests with no proper contact on the flanks. Although it may seem presumptuous to call such a screw a micrometer at all, it need not in fact have the accuracy of pitch that would be necessary in, for example, a measuring micrometer. Its main purpose is as a null-setting device, that is to say once the workhead has been brought to the right position by the micrometer screw and the adjustable thimble set to zero, that setting can be repeated for each tooth in turn.

The thimble is frictionally held to the screw by means of two steel balls and a centre spring located in a cross drilling in the body of the screw. In turning the circular recess for the balls in the thimble plant it a little bit deeper than the exact dimension so that the thimble is held firmly against the shoulder of the screw by the pressure of the balls. Engraving the thimble can be done directly from a 50 tooth change wheel but the engraving tool must be held in the topslide of the lathe set over to an angle of 30 °. Bearing in mind that the cut is put on as the screw is unscrewed, that is rotated anticlockwise, the numbers stamped on the thimble are in the opposite direction to that which is normal on

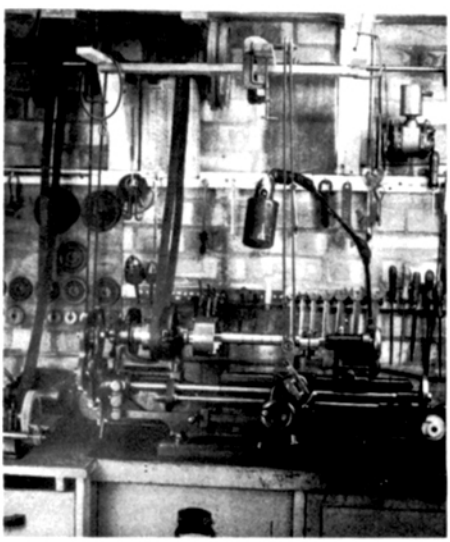


Fig. 8. Cutting a 1 in. pitch thread.

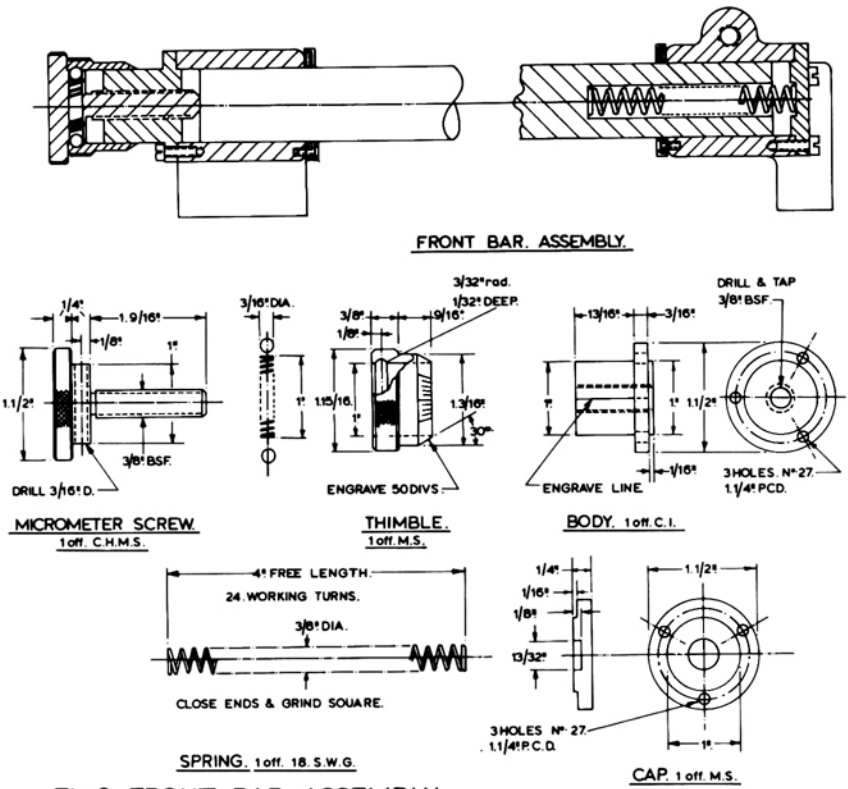


Fig.9. FRONT BAR ASSEMBLY.

a measuring micrometer. This is the only detail which would have to be changed if for any reason it was decided to fit the micrometer screw on the right-hand side of the machine. The anti-backlash spring, if made to the dimensions shown, will give a force of about 10 lb which is sufficient to overcome friction and hold the work against the wheel for light grinding.

A problem with all grinding machines is to find some way of keeping the inevitable grit and dust out of the working parts. After experiments with bellows, which were not very satisfactory because if it did get in it was even harder to get out, and running the machine dry, the prototype machine was fitted with felt wipers (not visible when the photographs were taken) and these have proved eminently satisfactory. The covers, shown in Fig. 10, should be as slim as possible and secured with countersunk head set screws because their combined thickness does limit the travel of the workhead along the front bar, particularly near the vertical column end. The amount of felt to put in them must be determined by trial and error but the writer found that three layers of felt 1/32

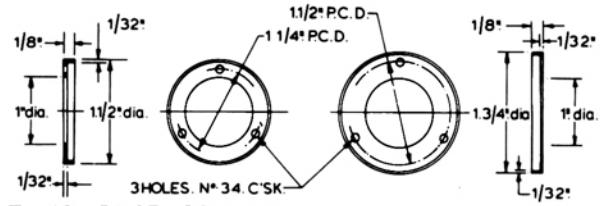


Fig.10. DUST COVERS.

in. thick of the sort used for making stuffed toys and cut to a close fit on the front bar was just about right in allowing reasonably free movement and at the same time giving a positive wiping action. Similar wipers are of course to be fitted to either side of the workhead, and all slots which would otherwise allow the ingress of grit and dust into the working parts are filled with "Plasticine", which, although it hardens to some extent, remains plastic, or silicone rubber sealant. The latter is available from most ironmongers as a sealant for baths, basins, windows, toilets etc. Nevertheless it is recommended that the front and rear and all the mandrels, arbors and collets used in conjunction with the machine be kept bone dry and wiped clean after use. If they are lubricated not only will they pick up more grit, which falls off a dry surface, but mixed with the oil will form a first class grinding paste which once it has got into the bearings will play havoc with them.

An essential adjunct to any cutter grinder is a tooth rest. With its aid many cutters can be ground without any dividing attachment whatever, each tooth as it is in turn brought into contact with the rest making the cutter self-indexing. This is particularly useful for cutters with large numbers of teeth and for which a suitable dividing plate may not always be available.

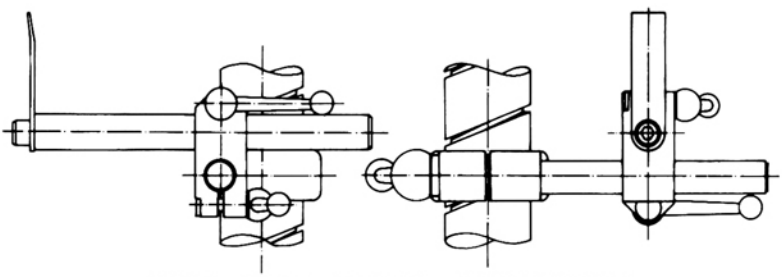
The Quorn tooth rest shown in Fig. 11 is clamped to the vertical column of the machine and comprises two round bars one of which carries, at its outer end, the blade which forms the actual tooth rest. It can therefore be set at any height or distance to suit the work in hand or the diameter of the wheel being used. It can also be used inverted, that is mounted on the vertical column above the wheelhead and with the blade pointing downwards, if, in certain circumstances, this gives a better view of the work.

The details should not present any difficulties.

The collar is an iron casting and can be quite easily held in a four-jaw chuck for machining the central hole. The clamp comes easily out of a piece of 3/4 in. square bright drawn mild steel and the holes will be sufficiently accurate if put in with a drilling machine. Chamfering the corners of the block is optional but it gets rid of a bit of unwanted metal and tidies the thing up somewhat. The bars can come out of 1/2 in. dia. bright drawn round mild steel, particularly if the holes in the clamp are bored or reamed to suit the size of stock being used. A small but important feature is the flat on the turned down bar which, engaging a corresponding shoulder machined on the collar, prevents the bar turning when the ball handle is tightened. As shown the bars are long enough for all normal

work within the range of the machine but an extra inch or more could be added to cope with abnormal work.

The tooth rest blade itself must be regarded as semi-expendable. It is always rather a fiddlesome job to get the blade into the narrow space between the tooth being ground and the face of the grinding wheel and although the shape shown in Fig. 11 will be found to be of general utility, sooner or later it will have to be modified to suit a particular job. Inevitably too the back will get ground away by inadvertent contact with the grinding wheel, but fortunately they are easy to make and are traditionally the best known use for the broken ends of hacksaw blades!



TOOTH REST. GENERAL ARRANGEMENT.

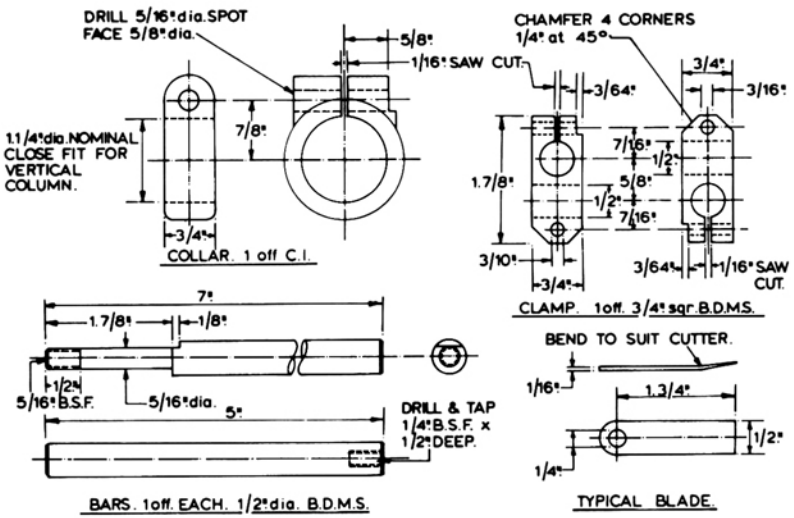


Fig.11. TOOTH REST AND DETAILS.

CHAPTER 3

The Wheelhead Assembly

The next group of castings to be machined could well be the wheelhead assembly (Fig. 12) particularly if, as has been suggested earlier, it is to be used to machine the spiral keyway in the vertical column.

Although both the Mk I and Mk II wheelheads are functionally interchangeable and operate on the same principles, there are differences in the basic castings and in the method of mounting the motor. The following description, therefore, although it applies to the Mk I will also note the differences to be observed in machining the Mk II castings.

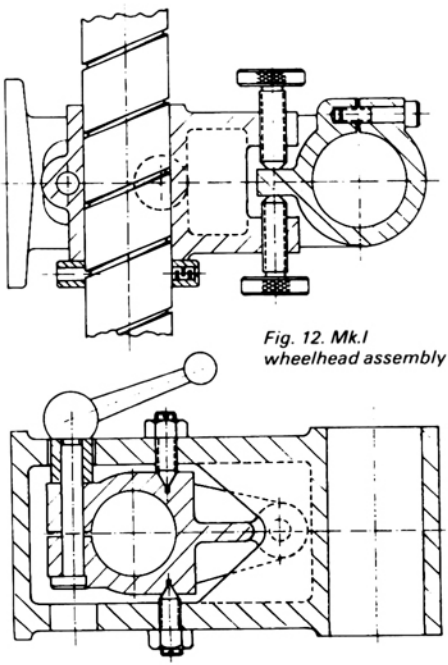


Fig. 12. Mk.I wheelhead assembly

The wheel-collar, Fig. 13, will swing in a 3½ in. lathe so that it can be held in a four-jaw chuck, with one jaw reversed, to machine the 1¼ in. bore to a neat sliding fit on the vertical column. At this setting one end can be faced but the other end must be faced by mounting the casting on a stub mandrel or on the vertical column itself. Incidentally all these "2nd Ops" of which there a number are very much facilitated if they are deferred until after the castings have been cross drilled for the clamping bolts and split. With a jury bolt through the cross hole they can be firmly and truly clamped to an appropriate bar used as a mandrel between centres. Alternatively the casting can be machined on the lathe saddle as in Fig. 14. In this case both ends can be machined at the same setting by a facing cutter mounted on the boring bar. Cross drilling, tapping and slitting, preferably with a circular saw in lathe or milling machine for neatness, but a hacksaw cut would do, are conventional. Some care needs to be exercised however in planting the $^{9}/_{32}$ in. dia.

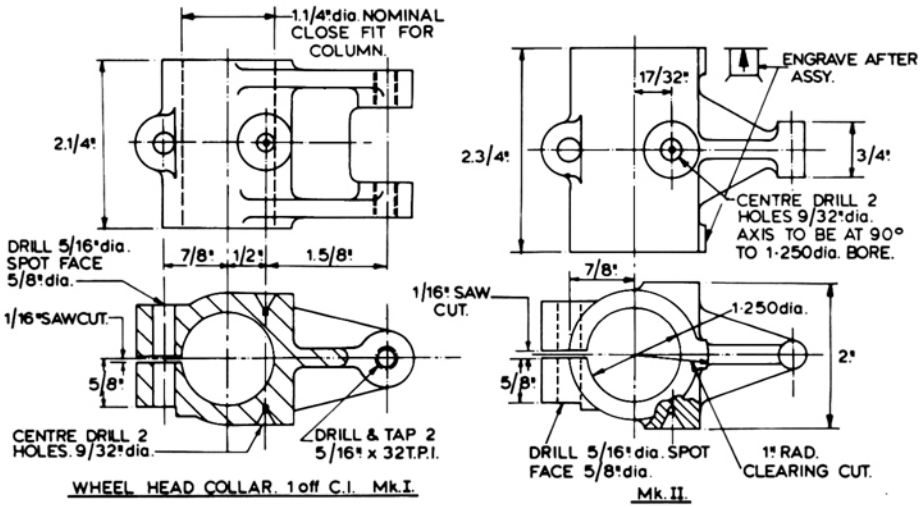


Fig.13. WHEELHEAD CASTINGS.

centre holes in which the pivot screws of the wheelhead bracket engage. Unless they are exactly the same height each side the axis of the grinding spindle will be canted and the faces of wheels mounted on it not truly at right angles to the bed bars. Some latitude for adjustment exists in the final assembly, which will be described in due course, but even at this stage it is well to get the work as accurate as possible. Jig drilling would be ideal, using the same jig to drill each side in turn, but hardly worth while for "one off". However, if the casting is packed up on the lathe saddle or mounted on a vertical-slide and brought to centre height both sides can be drilled in turn from the chuck without altering the height setting. As a check, clamp a 1/4 in. dia. steel ball in each centre hole and test its height with a D.T.I. from a surface plate.

If there is an error a square centre or a centre scraper will very quickly pull the hole a few thous in the right direction. This tip may be useful too to crankshaft

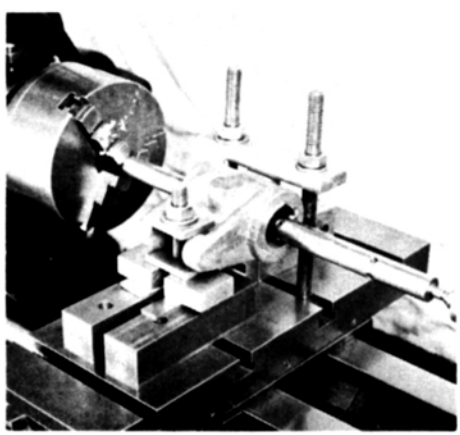


Fig. 14. Machining the collar.

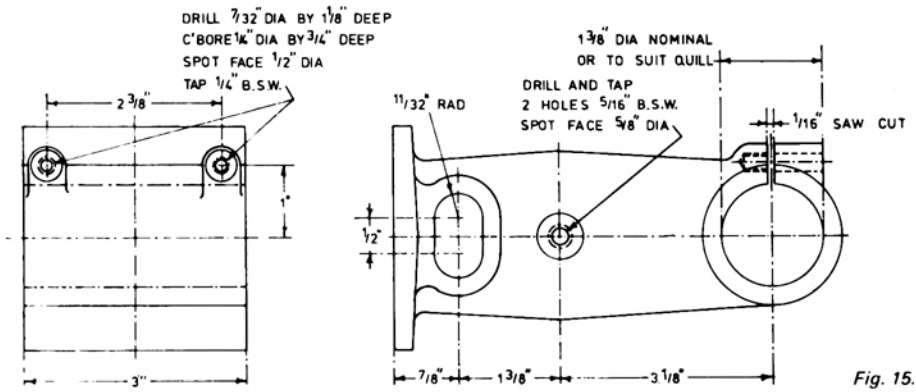


Fig. 15.

WHEEL HEAD BRACKET 1 OFF CI Mk.I

and eccentric turners who would like to have their throw plates the same both ends. Only a detail perhaps but it all counts.

The Mk I wheelhead bracket, Fig. 15, is too large to swing on the faceplate of a 3½ in. lathe but it can be quite easily set up on the saddle for boring the 1⅜ in. hole for the grinding spindle quill as in Fig. 16. There is sufficient metal in the casting to accommodate a range of sizes, say from 1¼ in. to 1½ in. dia. but as the writer has two other spindles with 1⅜ in. bodies this is the size he adopted. The second major operation is to face the flat surface for the motor mounting. A very similar setting to that used for the boring can be used again for this operation, but of course with the casting slewed around at right angles to face a

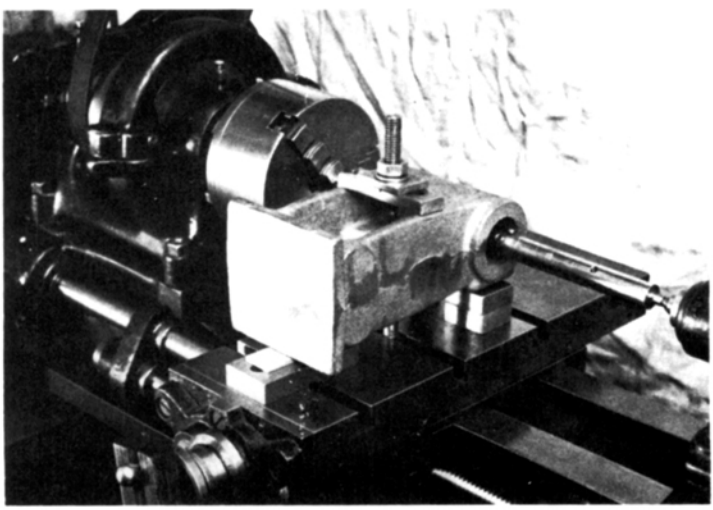


Fig. 16. Machining the bracket.

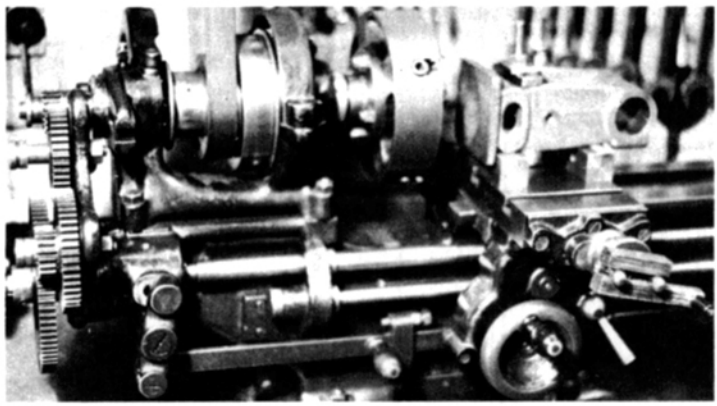


Fig. 17. Facin the base.

fly cutter held in the four-jaw chuck. Put a true 1⅜ in mandrel (the body of the quill which you have not yet turned does very nicely for this so wait for it!) in the appropriate hole and with a D.T.I. held in the lathe chuck make sure it is parallel to the lathe across slide-ways. Not strictly necessary in this job, but one day it may be, so gain the experience now. In Fig. 17 the lathe is in middle speed back gear, about 72 r.p.m. which with a fly cutter set at about 2 in. radius gives a cutting speed of about 38 feet/min. The change wheels are giving a feed of about ½ thou per rev, as I find that the best way to reap off cast iron with a light and somewhat elderly lathe is with a slow speed, a fairly deep cut, say 1/10 in. deep and a steady feed. Not to worry if the cutter takes off more metal at the back of its cut than at the front. Most lathes do this anyway if, as they should be, they are set to face concave and not convex. Just let the back cut right across the face and it will be as flat as makes no difference. Using this face as a datum the 1 3/16 in. x 11/16 in. slots for clearing the wheelhead collar locking bolt can be put in either by packing up on the saddle or by bolting to a vertical-slide, set parallel of course to the lathe axis. Owing to the draft on the casting some cleaning up of the inner faces of these bosses may be necessary before the wheelhead collar casting can be interposed between them. The other operations, including cleaning up the bosses upon which the micrometer adjustment screws will bear, are conventional.

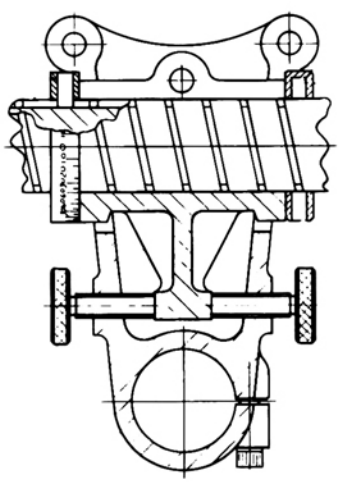


Fig. 18. Mk.II wheelhead assembly.

A cross section of the Mk II wheelhead is shown in Fig. 18 and machining the bracket, Fig. 19 is if anything easier; it was after all designed for production. In this case the first operation should be to machine the flat faces on either side of the casting true and parallel to one another. This can either be done on the faceplate of the lathe, since it is not essential that the casting to set true to any particular centre as long as it clears the bed of the lathe, or on a milling machine, vertical or horizontal. Using the motor mounting side of the partly machined casting it can then be very conveniently clamped to an angle plate bolted to the cross slide for machining the bore for the grinding spindle.

As in the case of the wheelhead collar, and for the same reason, particular care needs to be paid to the positioning of the 5/16 in. tapped holes which take the centre screws and upon which the assembly rocks. So first drill them undersize to fit any convenient piece of silver steel. With this in place, the 1⅜ in. mandrel in the quill hole and the job on a surface plate check with a D.T.I. that both bars are free from "warp and wind". Unless you are extraordinarily lucky they won't be, so draw them in the required direction with a round file, redrill to fit the next larger size of silver steel and try again. Before you reach 5/16 in. BSW tapping size you will realise just how inaccurate a drilled hole can be! If you can get them to say 0.001 in. in 6 in. you are doing very well indeed.

The other details to complete the wheelhead assembly are the adjusting and pivot screws in Fig. 20. One of the former will also be required for adjusting the rocking lever so make all three while you are about it. Only the tips of the screws need be case-hardened but unless you fear distortion it is no bad thing to case-harden the threads as well to combat the inevitable wear to which all grinding machines are subject. Knurling will be a test of your skill as a turner.

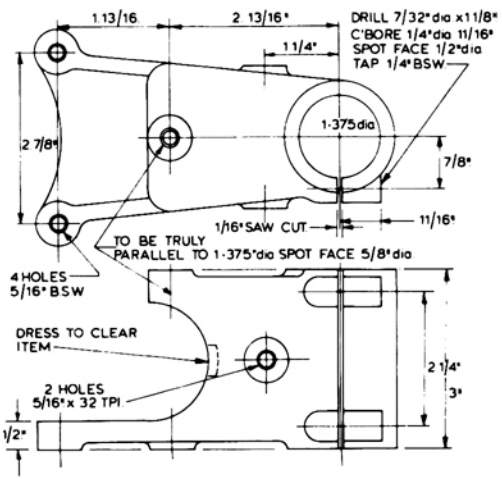


Fig.19. MkII WHEELHEAD BRACKET.

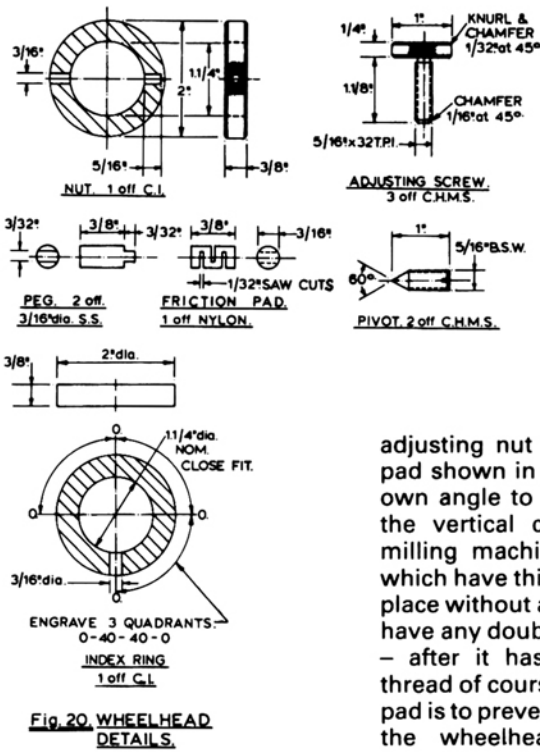


Fig. 20. WHEELHEAD DETAILS.

Do it before finally parting the screw from the bar while you have plenty of stock to hold it by. Chamfer after knurling to remove the ragged overhanging edges. The pivot screws are kiddies' practice jobs because, believe it or not, it is better that the 60 deg. conical points should not be too truly concentric with the screw threads. In the final assembly slightly eccentricity here will be used to take out any residual error in the rest of the machining. So if you make them too accurately you may have to make one again deliberately eccentric!

If you have opted for a screwed vertical column, now is the time to make the adjusting nut with its peg and friction pad shown in Fig. 20. The peg finds its own angle to match the spiral lead on the vertical column. On the writer's milling machine and grinder, both of which have this feature, the peg stays in place without any other fastening. If you have any doubt a dab of Loctite will fix it – after it has aligned itself with the thread of course. The idea of the friction pad is to prevent the nut backing off after the wheelhead is locked and the machine is running. As drawn it seems to give about the right friction, but this can easily be adjusted by altering the depth of the saw cuts. So make them rather less deep at first and deepen them until you have got the feel that you like best.

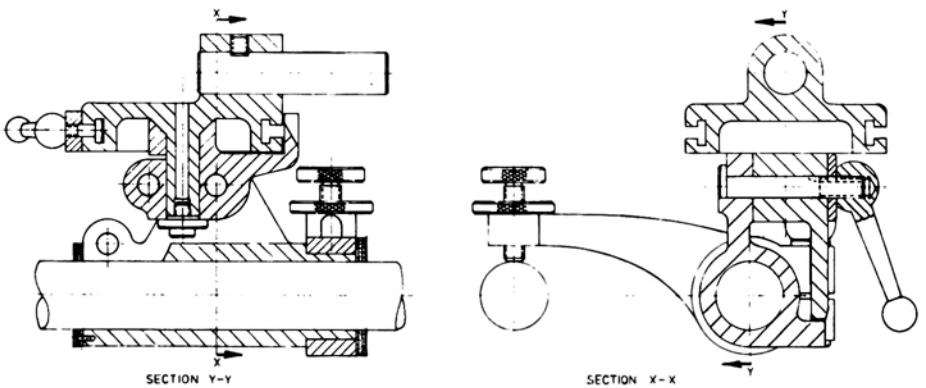
The index ring is a straightforward turning job. The pin key is similar to that used for the adjusting nut, 'Loctited' in place, but it must be a really good fit in the keyway in the vertical column as any backlash here would destroy the accuracy of the angular setting. Graduation of the degree setting may well be left until other parts are due for engraving and all the scales done at the same time.

CHAPTER 4.

The Workhead Assembly

The workhead assembly shown in Fig. 21 comprises four main castings. The base casting shown in detail Fig. 22 can either be clamped to or slide along the front bar of the machine. In the clamped mode the angular position of the workhead is controlled by the rocking lever which is in turn clamped to it. In the sliding mode the rocking lever also slides along the rear bar which becomes, in effect, the rear shear of the machine. A vertical extension on the base casting carries the tilting bracket, detailed in Fig. 25 which, as its name implies, is the means by which front and side rake is given to the tools being ground. It in turn provides the bearing for the rotating base, shown in detail in Fig. 29, which controls the front and side clearance angles and, when free to rotate between stops, provides the axis about which radii are generated in tool and cutter grinding. A boss on the head of the rotating base carries optional long and short bar beds upon which interchangeable tool and cutter holders and a tail centre may be mounted.

Commencing therefore with the workhead base, which is an iron casting, the first and most critical operation is to bore the long 1 in. dia. hole a really close sliding fit for the front bar. If your lathe is above suspicion for this kind of work, and mine is not, the procedure indicated in Fig. 23 can be adopted. The casting is held at the boss end in a four-jaw chuck and the far end, after dressing up the edges of the cored hole, supported on a



WORKHEAD ASSEMBLY

Fig. 21.

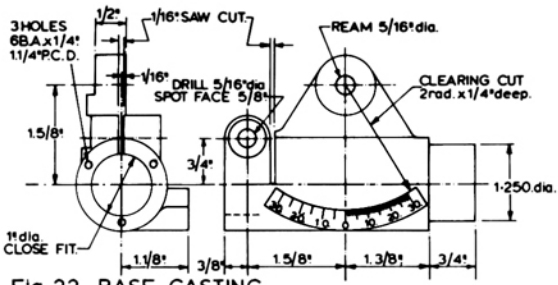


Fig. 22. BASE CASTING.

large tail centre, preferably a running one. Sufficient support is then given for the 1.250 in. dia. spigot to be turned to the finished length and diameter. The spigot then serves as a truly turned bearing for the fixed steady and in this way the casting is firmly supported front and rear for the long hole boring operation. Here it is essential that the fixed steady is absolutely truly adjusted because if it pulls the casting in the slightest towards or away from the lathe centre line the hole will not be parallel, even if the lathe in normal chuck work has been adjusted to bore parallel.

If you do not fancy this method, the casting can be quite easily clamped to the saddle of the lathe and the hole bored with a boring bar between centres, as was done for the base casting shown in Fig. 4. In this case you have assurance that even if the lathe is not in the pink of condition the hole will be the same size both ends. If boring the long hole is the first operation the second should be to cross drill and split the clamping boss after which, with a jury bolt through the hole, it can be readily clamped to one of the 1 in. dia. bars as a mandrel for turning the 1.250 in. dia. spigot and facing the ends.

The second critical operation is to bore and face the $^{5}/_{16}$ in. dia. hole which carries the pivot bolt for the tilting bracket as accurately as possible truly at right angles to the long 1 in. dia. hole. Although the casting has at its back a chucking piece it cannot, because of the moulding draft, be held securely in a chuck. So first file three or preferably four parallel flats on it so that it can be held without shake or wobble in either a

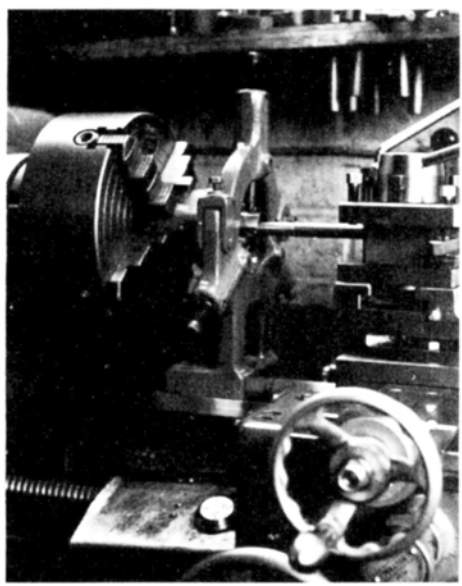


Fig. 23. Boring workhead base (photo N. Hemingway)

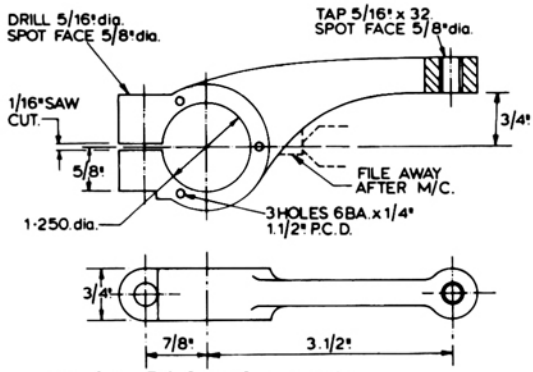


Fig. 24. ROCKING LEVER.

three- or four-jaw chuck. Put one of the 1 in. dia. ground bars in the already bored hole and in a "turn around test" with a dial test indicator held in the toolpost or on the saddle check that the reading is the same both ends. It won't be, so you will have to draw the flats on the chucking piece until the error is reduced to reasonable proportions, say .001 in. at either end. This is a very sensitive test and will serve to demonstrate that just grabbing a casting by the chucking piece and hoping for the best is not conducive to precision work. It is there for convenience in holding, not a jig to ensure accuracy. That you have to put in yourself.

Once truly chucked, the 5/16 in. dia. hole can be rough drilled, trued with a small boring tool and reamed to size. Take particular care that the face against which the tilting bracket seats is faced as truly as possible, slightly concave but never convex. The clearing cut for the pointer and facing the surface on which the protractor scale will eventually be engraved involve interrupted cuts so take it steadily, middle back gear, preferably with autofeed. Before breaking down this setting and while the surfaces are still running true it is very convenient to engrave the protractor scale and stamp the numbers. This will be dealt with in detail in connection with the rotating base and is the same for all the scales with which this machine is equipped. After it is complete the chucking piece will be machined away in the process of milling the seating for the locking bolt.

The slitting is best done with a circular saw about 4 in. dia. and care must be taken to stop the cut before the saw cuts into either the 1 in. dia. bore or the tilting bracket boss.

Thanks to a small nib on the inner side of the curved arm, suggested by Mr. A. Throp, the rocking lever detailed in Fig. 24 can now be conveniently and securely held in a four-jaw chuck for machining the 1.250 in. dia. bore a close fit on the already turned spigot of the base. At the same setting one side can be faced but the other is faced after cross drilling, slitting and clamping to any convenient piece of 1 1/4 in. bar set to run true in the four-jaw chuck. The nib may be filed away or left where it is.

The tilting bracket detailed in Fig. 25 is, in the prototype machine, a steel cast-

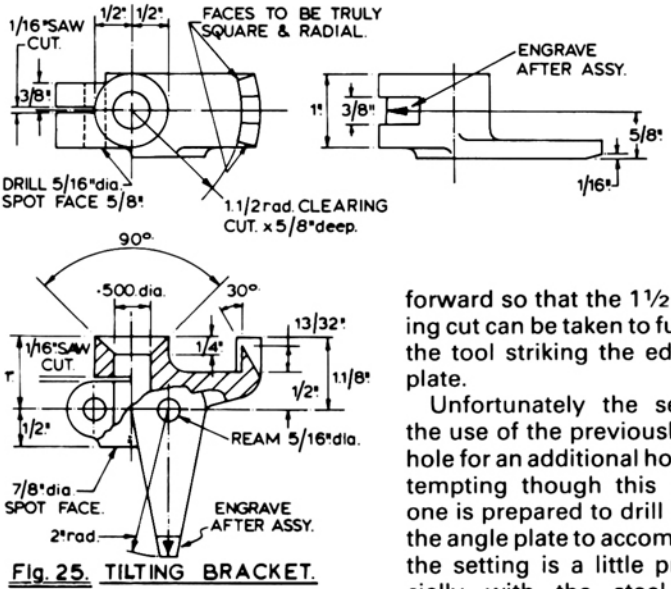


Fig. 25. TILTING BRACKET.

ing, but owing to foundry difficulties in running, the long pointer is now replaced by a gunmetal casting. It is an interesting piece to machine and in spite of its complexity not difficult if the right sequence of operations is followed. The first is undoubtedly to hold it in the four-jaw chuck, as in Fig. 26, with a bridge piece of bright mild steel across the boss and the stop face to spread the load. In this setting the 5/16 in. dia. hole can be rough drilled, bored true and reamed to size and the index finger faced flat to serve as a datum face for all subsequent operations.

For the second operation, shown in Fig. 27, the casting is clamped by its tail with this face in contact with an angle plate secured to the face-plate of the lathe. It must, however, be set rather far forward so that the 1½ in. radius clearing cut can be taken to full depth without the tool striking the edge of the angle plate.

Unfortunately the set-up precludes the use of the previously drilled 5/16 in. hole for an additional holding down bolt, tempting though this may be, unless one is prepared to drill a special hole in the angle plate to accommodate it. Since the setting is a little precarious, especially with the steel casting being machined here, it is prudent first to rough machine the face of the 1 in. dia. boss and then to put a centre in it for

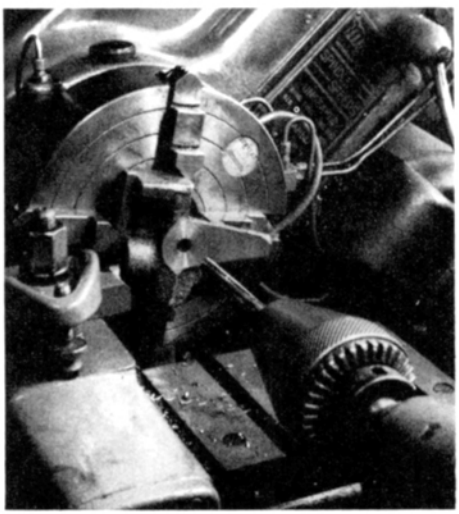


Fig. 26. First machining operation (photo A. Throp)

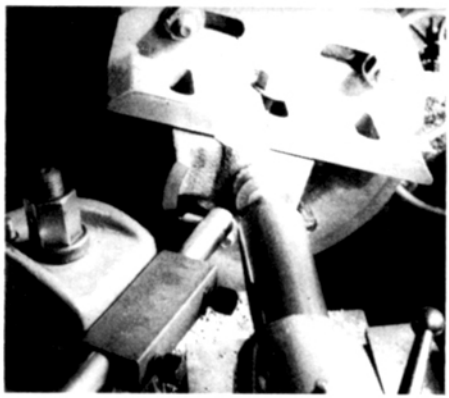


Fig. 27. Second machining operation (photo A. Throp).

tailstock support while the interrupted clearing and facing cuts are taken across the stop lug as in Fig. 27. After they are complete the tailstock can be removed and the ½ in. dia. hole and the 90 deg. seating can be machined in the usual way as shown in Fig. 28. Particular care should be taken with these bores as they form, in fact, the single bearing in which the rotating base turns. They should therefore fit as closely as a precision lathe mandrel bearing.

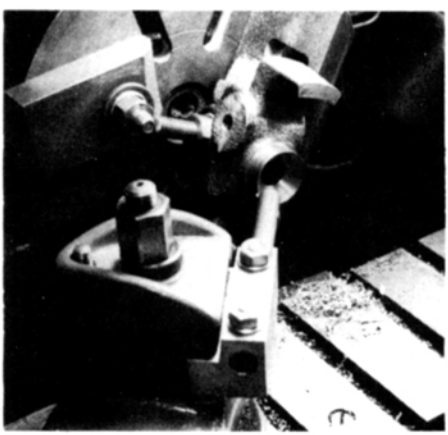


Fig. 28. Taper boring the bearing seating (photo A. Throp).

After cross drilling and slitting, this time with two cuts intersecting at right angles to give adequate flexibility without cutting into the 90 deg. bearing face, the reverse faces of both the ½ in. and 5/16 in. dia. holes can be machined by mounting the casting on stub mandrels. Again care must be taken, particularly in the case of the 5/16 in. bore, that the facing is truly radial and if anything slightly concave. The stop faces and the slope for the index mark can be filed or, as in the writer's case, more accurately and quickly milled in the Dore-Westbury milling machine with the casting clamped to an angle plate on the table of the machine. At this stage do not put in the index marks, they will be marked off after the machine has been completely assembled and set true in a "turn round" test. These small castings tend to be rather lumpy and the moulding draft to be excessive in relation to their size so after all major machining is completed it is no bad idea, using the bored holes as datums, to do a bit of external carving, including the curve at the bottom of the stop face which cannot easily be moulded.

The rotating base detailed in Fig. 29 is a rather formidable looking steel casting, which in this case has been retained as such both to give adequate strength and the contact of dissimilar metals in the overhung pivot and to provide a tee slot which will stand up to the rigours of commercial misuse. However unprepossessing the steel castings may appear they are in fact of highest quality,

free of hard spots and with all surface scale removed by pickling and shot blasting. Once machining has begun they machine like free cutting mild steel, which indeed they are.

The sequence of operations which the writer found best with a light lathe, although others are possible, was first to clean up the top face and then to bolt the casting, upside down as it were, to an angle plate on the lathe faceplate. In Fig. 30 the scribing block is being used to bring the previously marked out centres into line before machining begins. At this setting the 5/8 in. dia. hole can be bored a close fit for the ground steel stock from which the bar beds will be made and the boss truly faced to provide a datum face for the second operation. For this instead of using an angle plate which would have given rather a lot of overhang, the writer used a piece of 1 in. x 1 in. bright drawn square steel stock in which appropriate holes were drilled in strategic places. Further to steady the work, packing pieces were inserted between the top face of the casting and the lathe faceplate as can be seen in Fig. 31. Because quite an amount of heavy cutting has to be done in cleaning up the inside of the casting and in roughing down the spigot to within say 1/32 in. of finished size, the end should be faced and centred for support from the tailstock, as was done in the case of the tilting bracket. The presence of sundry bolts and clamps will probably make it impossible to turn all of the outside diameter and certainly not to form the "T" slot at this setting so turn as much as possible to provide a true witness for subsequent setting. When all the rough-

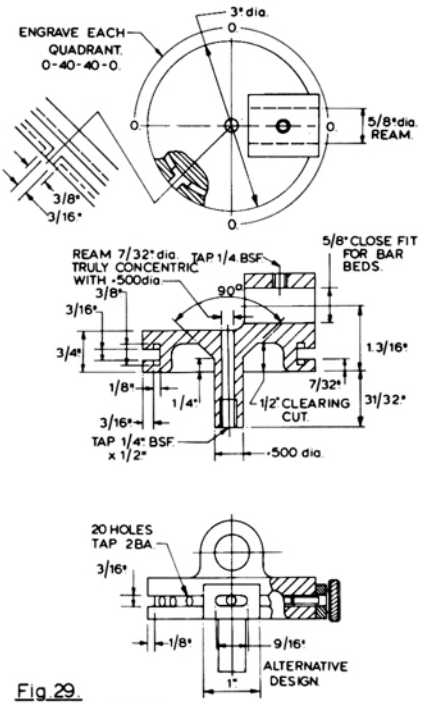


Fig. 29.
ROTATING BASE.

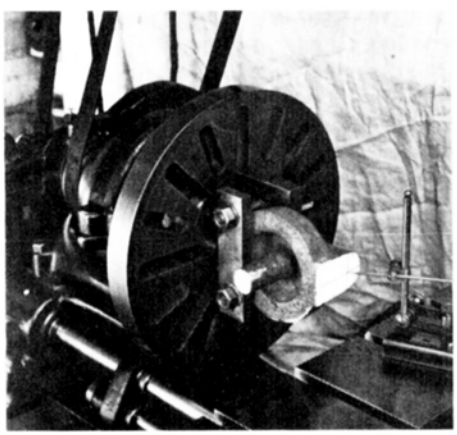


Fig. 30. Lining up the marked-out casting.

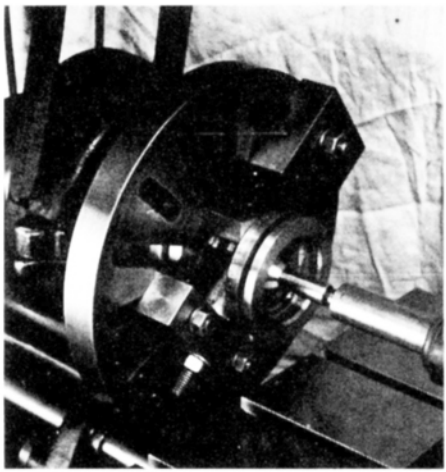


Fig. 31. Machining the spigot and index ring.

ing is done remove the tailstock and with light cuts turn the spigot to a close fit in the tilting bracket. The 90 deg. taper must also be turned with a sharp tool and the topslide set over to 45 deg. Check with marking blue that the tapers exactly match. The central hole which will carry the setting pin must be dead concentric with the turned pivot. Open out the centre for about its full depth with an undersize drill then with a tiny boring tool slowly enlarge the hole until it is an exact fit for a 7/32 in. dia. "D" bit. Given an absolutely true start this way a "D" bit will produce a true and straight hole, rather better if it is cutting into solid metal than if it is opening out a previously drilled hole. It needs of course to be withdrawn frequently to clear the swarf as it has very much less capacity in this respect than a twist drill. Finally face the spigot to length and tap no more than ½ in. of the 7/32 in. hole ¼ in. BSF. This completes the work at this stage with all the essential surfaces machined at the same setting and therefore truly concentric with one another.

For the next setting, the casting may be held in the four-jaw chuck but with the jaws opened outwards to hold the casting by the previously cleaned up internal recess. This is an extremely rigid setting and much preferable to holding the casting by the finish-turned spigot which might mark or damage it. The casting is set to run true by reference to the previously turned witness on the outer body. The circular tee slot is now put in three stages. First a straight square bottomed groove 3/16 in. wide by 5/16 in. deep, two cuts say with a 3/32 in. wide parting tool, with the lathe running in low back gear and plenty of cutting oil. To produce the undercut part of the tee slot a special tool will be necessary. If the lathe has a taper mounted chuck which can be run backwards without unscrewing, a single ended tool can be used, first at the front with the tip pointing say to the left and then again at the back, still the right way up, but now with the tip pointing to the right and the lathe running backwards. If your lathe will not perform this little trick you will have, as the writer had, to make a double ended tool such as that shown in Fig. 31a. Here again the Dore-Westbury comes into its own. With a piece of tool steel held in the machine vice on the table and a 3/16 in. dia. end mill in the chuck by slewing the vice this way and that against a bevel protractor all the clearance angles can be put in the twinkling of an eye and right first time before hardening the tool. The top rake of 10 deg. is important. Without it the chip will not curl and will jam in the cut. Of course when your Quorn is finished you will be able to grind all these angles after hardening but for the time being you will have to

stone up the edges by hand. True up any remaining part of the outer diameter which could not be reached in the previous operation.

An interesting alternative to facing the rigours of machining a tee slot has been suggested by Mr. A. Throp. It is to turn a plain groove 3/16 in. wide by 1/8 in. deep in the circumference of the base and to drill from it a number of equally spaced tapped holes, say 20 at 18 deg. intervals. The stop blocks would then have slots in them long enough to span from one hole to the next so that they could in fact be fitted anywhere on the periphery of the base. This idea, although perhaps not quite so handy as the continuous tee slot, would work very well if the holes were so positioned that in the normal "in line" or "at right angles" positions the stop blocks were in the mid position of their travel. With 9 deg. to go either way it would seldom be necessary to move to another hole for most backing off and clearance angle operations.

ENGRAVING THE DIVISIONS

In either case, before the work is unchucked and while it is still running true the degree divisions should be engraved and the numbers stamped upon it. Readers who have dividing heads, such as the M.E.S. to which the lathe chuck with the work still in it can be transferred, or who have dividing heads which can be attached to the lathe mandrel, will have no difficulty with this operation. But the writer has none of these things and has long used the lathe change wheels for all sorts of dividing operations. Although in the days of cast gears this may have been a dubious practice, modern gears are hobbed on machines which have master worm wheels at least as accurate as a division plate. The problem of backlash is overcome once and for all by putting the lathe in back gear, wrapping a string around the belt pulley and tying a heavy weight on to the end, see Fig. 32, which owes nothing to Heath Robinson! The resultant torque is more than enough to take up all the backlash and to resist any tendency for the work to shift under cutting loads.

The only remaining problem is to find a train of gears which will give 360 divisions. The 60 T wheel is a good start but needs gearing down 6:1 to give 360 divisions. A compound gear train of 20/40 and 20/60 will do it but there are not two 60 T wheels. So, long ago, the 60 T wheel was used to produce, by direct copying, a ring of 60 holes in a brass disc which engages with any of the lathe change wheels and can be fitted on to any stud. By now it has more than one row of holes in it, some with very odd numbers indeed. So this disc, used in place of a second 60 T wheel, is put on the second

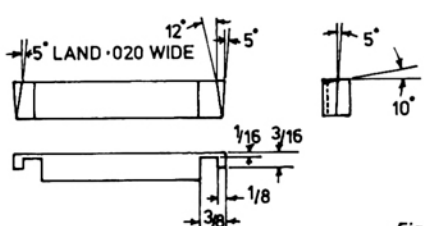


Fig. 31a.

stud along with a 20 T wheel and indexed by a conventional stop pin. The first stud carries 20 T and 40 T wheels, the former meshing with a 60 T wheel on the mandrel. Thus one hole in the brass disc turns the mandrel

$\frac{1}{60} \cdot \frac{20}{40} \cdot \frac{20}{60}$ of a revolution, that is, 1 deg.

The actual engraving is done with a sharp pointed "V" tool, like a screw cutting tool, set on its side with the point exactly at centre height. To ensure that all the lines are of equal length use the feed screw micrometer dials to control the length of cut. On the rotating base, because of the overlap of the reader, the one degree lines are 1/8 in. long, the 5 deg. 3/16 in. long and the 10 deg. lines 1/4 in. long. On the workhead base they are 0.1 in., 0.15 in. and 0.2 in. long respectively. With a 60 deg. engraving tool point the depth of cut should be .008 in. to give a line .010 in. wide. Before engraving starts the position of the zero marks must be aligned to the axis of the tool and cutter holders so temporarily slip the long bar bed into position and either set it vertical with a set square as in Fig. 32 or horizontal by checking each end with a dial test indicator from the saddle of the lathe. As engraving 270 divisions is in any case a tedious task and one in which it is easy to make a mistake in counting the long and short lines, the writer placed five washers on the right hand side of the lathe and transferred one to the left hand side each time a line was engraved. When they have all gone, engrave a 5 deg. line. Transfer them back again one by one as each line is engraved and when the pile is complete again do a 10 deg. line. It worked, but calls to tea, the telephone and "the downstairs loo is flooding again" demanded more than one recount!

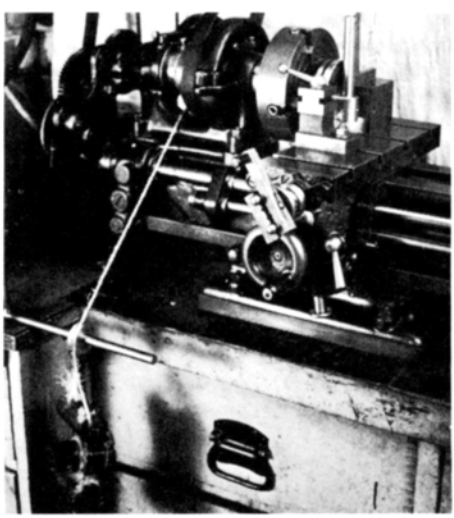


Fig. 32. Set-up for engraving 1° divisions.

While the dividing gear is set up, it is well worth while to use it to position the numbers. The writer used 3/32 in. number stamps and rigged up a simple guide from mild steel strips so that each stamp could be repeatedly located in the same position. By movement of the cross slide single digit numbers were brought exactly in line with the scale lines and the two digit numbers equally spaced either side of them. But remember, as our printer knows, that 30 takes up more space than 10. As most work in tool and cutter grinding involves the measurement of small angles away from a truly longitudinal or transverse axis, instead of marking the scale from 0.270, the writer numbered each quadrant of his machine 0-10-20-30-40-40-30-20-10-0. This seems to work very well and if, for example, one does want 75 deg. it can of course be set at 90-75 deg.,

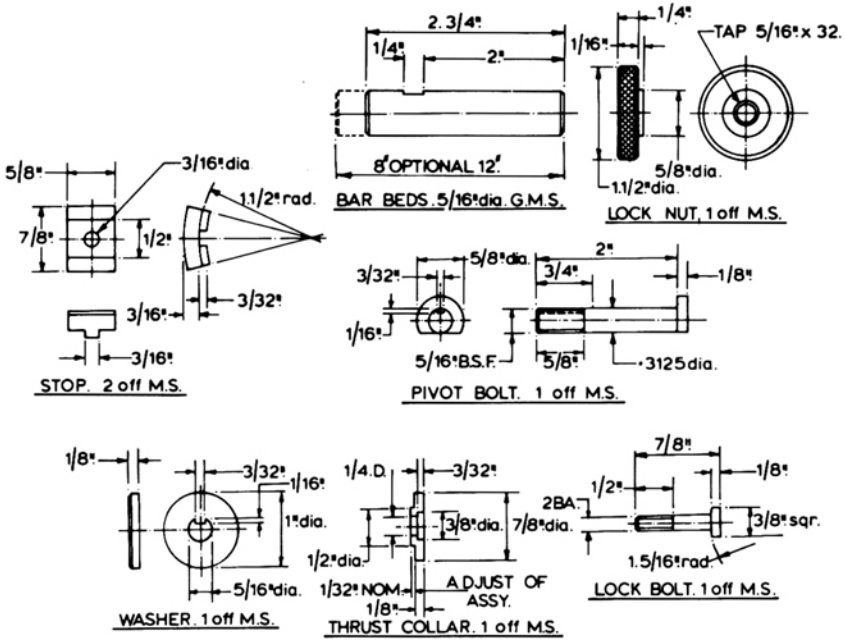


Fig. 33. WORKHEAD DETAILS.

that is 15 deg. measured from the other end of the quadrant.

When the engraving and stamping is finished, the appearance of the work, and particularly of the stamped numbers, is vastly improved if, with a very sharp graver but under no circumstances emery cloth, the burrs raised by the punches are cut down to the surface of the work. Done carefully the result is not all that inferior to true engraving which of course produces no burr.

The other details to complete the workhead assembly are shown in Fig. 33. The stop blocks are most easily machined in the form of a complete ring, either from a solid disc, from a slice cut off the end of a thick walled tube, or from a ring bent up hot from 3/4 in. x 1/2 in. strip with the joint welded, brazed or soldered. One ring will of course make enough stops for several machines so friends should get together. Alternatively sweat two 3/8 in. x 5/8 in. x 7/8 in. blocks on each end of a bar 3 3/8 in. long, hold it in the four-jaw chuck and with light cuts scoop out the interior. If you clamp it to the lathe faceplate with the blocks under compression you can use "Loctite".

The pivot bolt which joins the tilting bracket to the workhead base is a special one. Not only must it be a close fit in the 5/16 in. reamed hole in the bracket, in which it serves as a journal, but it has a keyway to engage the special anti-rotation lock washer. This was found to

be necessary because on occasion pressure on the tool holders sometimes caused a plain washer to turn and so to loosen the grip of the ball handle. The hole in the lock washer can simply be filed to shape by those who have such skills, but the writer uses his long suffering lathe as a slotting machine for such jobs. Starting with a $^{3}/_{16}$ in. dia. pilot hole and with a suitable tool held endways in the toolpost most of the metal can be nibbled away. It is then fairly easy with needle files to clean up the key itself to a nice fit in its keyway. Alternatively a transverse $^{3}/_{32}$ in. hole could be drilled in the bolt and a silver steel peg pressed in to engage with a straightforward keyway in the lock washer.

If you like ball handles, and with them the machine can be operated entirely without the use of any spanners or keys, 15 are wanted, so defer making any until you have the tools, to be described later, with which you can make the whole lot in one session.

The $^{1}/_{32}$ in. shoulder on the thrust washer is a nominal dimension. Leave it full and after the rotating base has been fully fitted to the tilting bracket face it down until the base is just free to rotate but without any end shake. If the 90 deg. cone beds down in use you can always face a bit more off the thrust washer or, if you overdo it, make another one! In good design the expendable component should always be the cheaper one!

CHAPTER 5.

The Tool-Holder, Arbors, Mandrels and Collets

The tool-holder shown in Fig. 34 is a versatile piece of equipment into which a wide variety of arbors and mandrels, all of which can be made by the amateur to suit his individual needs, can be fitted. It comprises a cast iron bracket which can be clamped at one end by the standard split boss, lock bolt and ball handle to either of the long or short bar beds at any point along their length. At the other end it has a parallel hole, again with a split clamp, to carry the various arbors and mandrels. For work such as lathe tools and engraving tools which must be turned a prescribed amount for a datum face in order to impart clearance angles, an interchangeable index plate is provided. It is graduated in 360 divisions and has 12 or more index holes which are engaged by a retractable spring-loaded index pin housed in the main casting.

The main casting shown in Fig. 35 is one of three which it is convenient to machine together, the other two being the head bracket and the tailstock. They are intended to be interchangeable and in particular that the centre height, shown on all drawings as a nominal 2.000 in., should be as closely as possible the same on all three components even if it is not an exact 2 in. by N.P.L. standards. Therefore first machine the lower 5/8 in. dia. hole in each casting to a close fit for the 5/8 in. centreless ground round bar or bright drawn bar if that is what you are using. For this operation the castings are small enough to be held in the four-jaw chuck. After boring, cross-drill, spot face, split and fit a temporary clamp bolt.

It is now necessary to improvise some form of temporary fixture in which each of the castings in turn can be located from this hole for boring the next. In Fig.

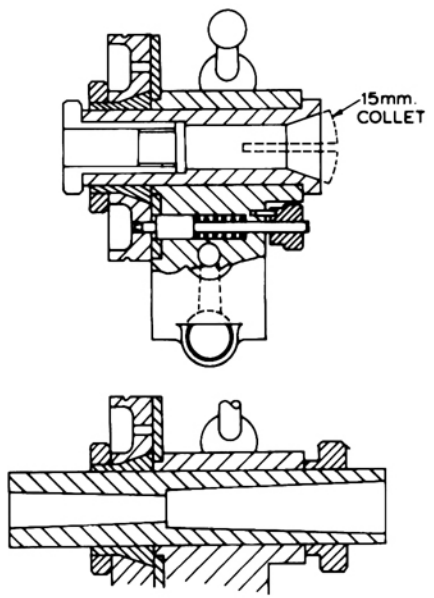


Fig.34. TOOL HOLDER ASSEMBLY.

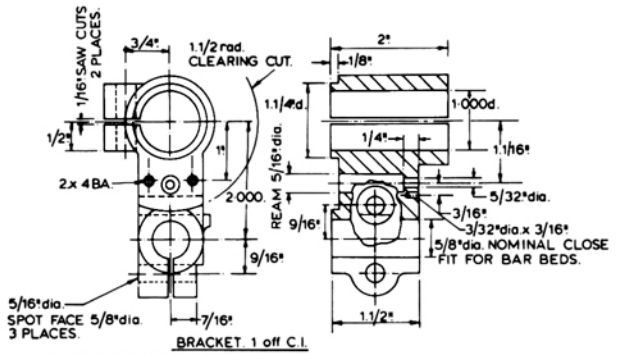


Fig. 35. TOOLHOLDER CASTING.

36 a piece of 5/8 in. bar has been clamped in a "Myford" or "Keats" type V block itself clamped to the lathe faceplate and offset 2 in. from the centre line of the lathe. Once set, it must not be moved until all three castings in turn, clamped by their split bores, have been machined at the other end. Although this set-up was perfectly successful it does rely upon very secure clamping–if the casting should slip disaster would ensue. Also, as witness the massive balance weight, it is rather out of balance.

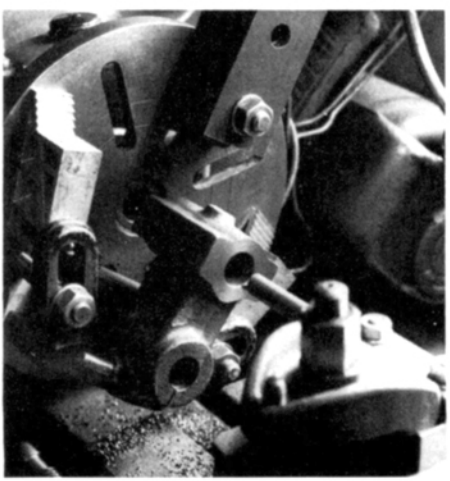


Fig. 36. Machining the casting (photo by A. Thro

A rather safer set-up, which howeve involves a little more preliminary worl is shown in Fig. 37. Here a shouldere stub, 5/8 in. dia., with a broad and trul faced flange, has been bolted to th lathe faceplate, again at 2 in. offset di tance. The casting can either be clampe to it, as in the previous example, or, as the photograph, held to it by a bridl The important additional feature hov ever is the two angle plates which bu up against the casting on either side ar so effectively prevent it from movir under the pressure of the boring too Although the castings shown here are fact those for the spiralling head tl others can be dealt with in exactly tl same way, only altering the distan between the angle plates.

Alternatively, all three castings m be machined on the saddle of the latl with a boring bar between centres, was described for the base castinç Having the necessary tackle to hand, tl writer did his this way, relying on tl cross-slide feed screw setting to brii the centre distance of the hole the san in each case. It is a moot point which

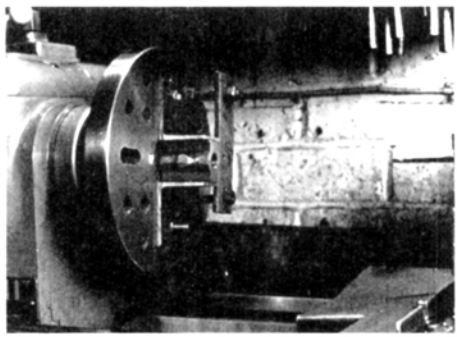


Fig. 37. An alternative set-up (photo by N. Hemingway).

the better. Cross-slide boring certainly ensures that the holes are parallel but the centre distance may vary. Locating from an eccentric spigot certainly ensures that the centre distances are identical to very close limits but unless the spigot is dead at right angles to the faceplate and the faceplate itself dead true the holes may not be parallel. So you pays your money and you takes your choice.

The rest of the machining is conventional, but before boring the 5/16 in. dia. hole for the index pin you must decide whether you are going to make this hole first and to locate the holes in the index plate from it, or whether you are going to make the index plate first and locate the hole for the index pin from it. Unless of course your equipment and skills are such that you can make both separately and know that the index pin will enter the holes in the index plate without jamming or backlash when they are assembled.

Other details for the tool holder are shown in Fig. 38. The backplate can most conveniently be made from sheet steel, either bright or blue. The outer rim should be left with a good finish as it will eventually carry the engraved zero mark. The index plate had best come from a sawn 3¼ in. x ¾ in. blank. If you can only get a 3 in. blank, not to worry. Just reduce the size of the backplate and index ring to one to which it will just clean up. The set-up for engraving 360 divisions is exactly the same as that for engraving the rotating base, again holding the index plate from the inside on the jaws of the four-jaw chuck in the "lathe" position.

If you have a milling and drilling spindle which can be mounted on the toolpost or are going to use the Quorn's own spindle for this purpose it is very convenient to drill the holes in the index plate at the same setting and using the same means of dividing. On the drawing I have shown 12 holes. This gives divisions of 2, 3, 4, 6 and 12, but any other number can be chosen. Thirty is probably the next best choice, as it gives 2, 3, 5, 6, 10, 15 and 30 divisions but not of course 4 or 12. The degree scale should be numbered as was the rotating base 0-40-40-0 in each quadrant taking care that the zeros coincide at least approximately with the holes. Minor errors can be corrected after final assembly by engraving the zero mark on the backplate exactly in line with a zero mark on the index plate after it has been locked in position by the index pin, duly fitted into a hole which has been spotted from the index plate itself.

If a milling and drilling spindle is not available, the tool holder itself can be used as a drilling and dividing jig. In this case first drill the hole for the index pin in the main casting and fit in it, temporarily, a bush 5/16 in. outside diameter and ⅛ in. internal diameter. Engrave a zero mark on the backplate and assemble the undrilled index plate in its work-

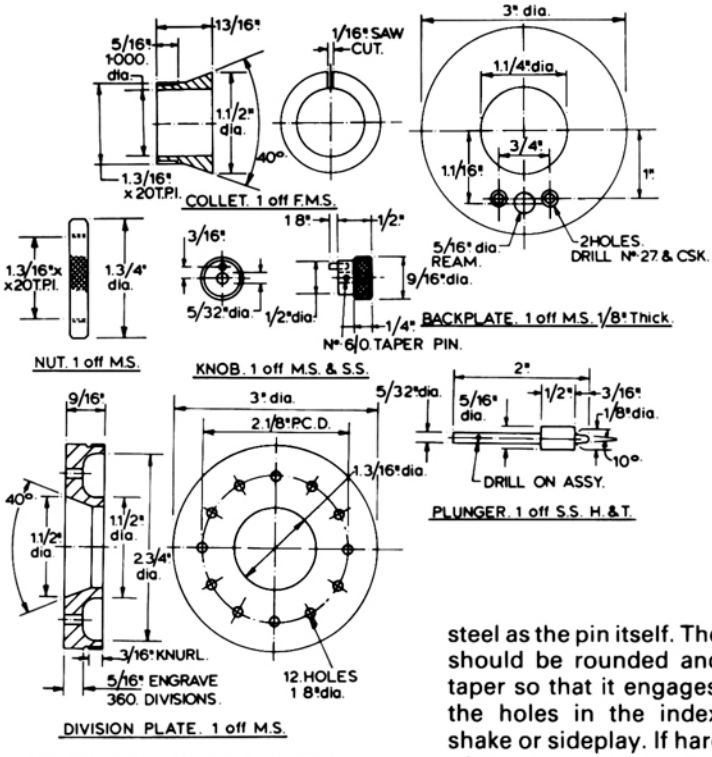


Fig. 38. TOOLHOLDER DETAILS.

ing position. Then by setting the degree scale at 0 deg., 30 deg., 60 deg., etc. and locking the spindle each time, the holes in the index plate can be drilled through the bush in the certain knowledge that they will not only be exactly in line with the index pin when it is fitted but that the degree marks will exactly coincide with the hole positions.

The $^{5}/_{16}$ in. dia. body of the index pin should be a very close fit, without any shake or backlash, in the hole in the casting. The latter should be reamed to size or, an old trick, finished to size with a 'D' bit made from a piece of the same silver steel as the pin itself. The point of the pin should be rounded and given a slight taper so that it engages positively with the holes in the index plate without shake or sideplay. If hardened, the point of the pin should be drawn back to purple temper colour to avoid brittleness which might cause it to fracture. The knob should be taper pinned to the shank of the index pin in such a position that the latter can go right home into the index plate without the knob making contact with the face of the casting. The $^{1}/_{16}$ in. dia. pin in the knob itself should be long enough to hold the index pin quite clear of the index plate when it is parked on the face of the casting and the degree scale is being used.

A great deal of the versatility of the machine depends on the wide variety of simple arbors and mandrels which can be fitted to the workhead. Some typical

ones are shown in Fig. 39. The first has a 9/16 in. square hole in it, the same size as the hole in the "Norman" toolholder on the writer's 3½ in. Drummond lathe. It will take all lathe, planer and shaper tools with shanks up to this size. Experts with a file will make the square hole this way, but if you can beg, borrow or steal a 9/16 in. square broach and a press to drive it the work is much easier. Probably the most effective way is to take a leaf out of the locomotive builder's book when they are making spring buckles and to make it in two parts. So end mill a 9/16 in. wide by 9/16 in. deep slot in a piece of 1¼ in by ⅞ in. bar about 3 in. long and silver solder or braze it, open side down, to a piece of 1¼ in. by 5/16 in. strip of the same length. After cleaning and pickling, drill and tap the four holes for the clamp screws and use them to hold the work on a truly centred 9/16 in. square mandrel. At this setting the corners can be turned off and the outside brought to finished size.

An alternative method of making the square hole using the slotting attachment designed and made by Mr. Throp * is shown in Fig. 40. Starting with a 9/16 in. diameter round hole a special tool, shown in more detail in Fig. 41, is used to

*See Model Engineer Vol. 144, p.1395, 1 December 1978

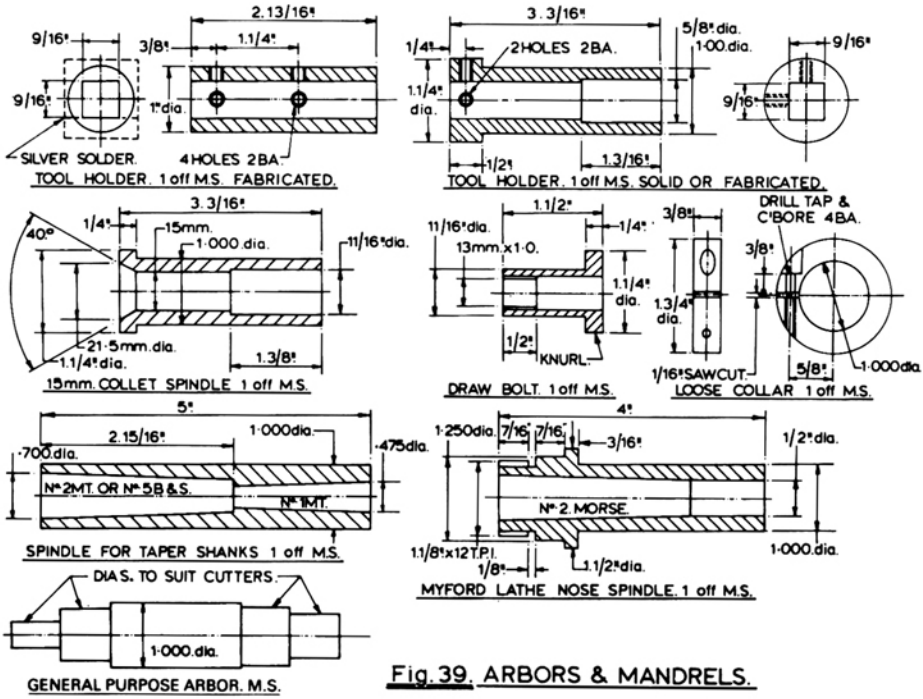


Fig. 39. ARBORS & MANDRELS.

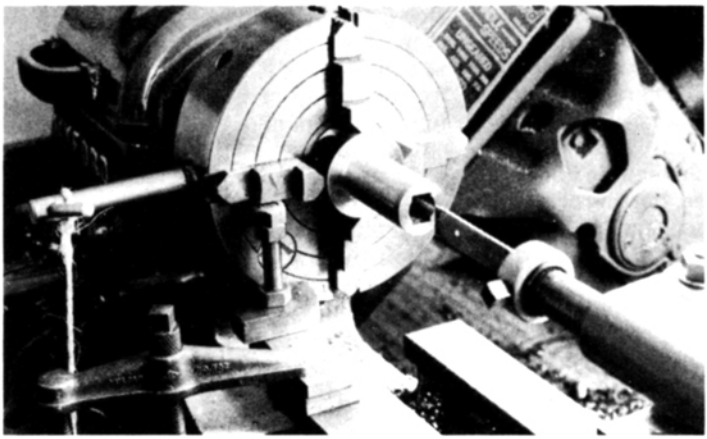


Fig. 40. Slotting a square hole.

convert the round hole to a square one by traversing the cross slide outwards. The cut cannot be taken to full depth in a single setting, it would become too wide, so when it has gone about halfway the work is indexed through 180° and the same process repeated on the other side of the round hole. This is the stage that has been reached in the photograph and if the work is now indexed first to 90° and then to 270° the slotting tool can complete the square hole without ever, except in the final stages, having to take an excessively wide cut. It will be noted that the jaws of a 4-jaw chuck are being used for indexing, held against a stop temporarily clamped to the lathe bed by a weight attached to the chuck key – a very simple and effective method which, with any modern chuck of good manufacture, is surprisingly accurate.

In using the holder, readers may be worried that only tools with 9/16 in. square shanks will be held "true" and that tools with smaller shanks will, of necessity, be held off centre. This is of course true but it does not matter in the least, nor is it necessary to make a series of holders each with a hole to suit the shank sizes of individual tools. In grinding square or rectangular shanked tools all that is important is that the various rake and clearance angles bear an accurate relationship to the base of the tool. This will be the case if the tool is turned through a known angle regardless of whether it is "on centre" or not.

This form of tool holder can and must be withdrawn from the workhead to operate the 2 BA clamp screws which must not project beyond the circular body. Although this is an advantage in examining the progress in grinding the cutting edge, and it can always be put back in exactly the same position afterwards, it is a disadvantage if the length ways position of the tool needs to be changed during the initial setting up process. Since it has been found by practical trial that two 2 B.A. setscrews will hold 3/8" or 1/2" square shank tools firmly enough for all normal re-sharpening operations an alternative design is offered in which knurl headed set screws are positioned outside the tool holder body so that they are at all times accessible. It can be made as before from a 'U' section brazed or silver soldered to a flat plate,

but ½" longer, which, after it has been turned to a circular cross section can have a thickening ring 'Loctited' to it or from the solid using the slotting tool technique. The points of the clamping sc ews should be case hardened otherwise they will burr up in use and be difficult to withdraw should it ever be necessary.

An equally useful spindle is one that will take collet chucks. The drawing in Fig. 39 is dimensioned for 15 mm "short" 'C' size standard collet chucks with a draw spindle to suit. This is a useful size since it will pass ⅜ in. and will accept ½ in. for a limited distance at the nose. But the spindle is big enough to take any size of collet from 6 mm to 16 mm, long or short. By modifying the front end and boring it No. 2 Morse taper so that it is a replica of the Myford lathe mandrel nose the "push-in" type collets supplied by that company could also be used. Any form of collet will, however, be found to be extremely useful in dealing with round shank tool bits and plain shank cutters.

In making these spindles which rotate in the workhead it is imperative that the nominal 1.000 in. diameter is a close running fit in the body. If the accuracy of collet chucking is to be preserved, boring the inside of the spindle truly concentric with the outside is always a problem. The work cannot very well be accomplished at a single setting, so probably the best way is first to complete all the external work, either between

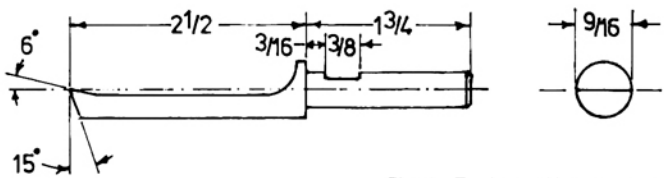
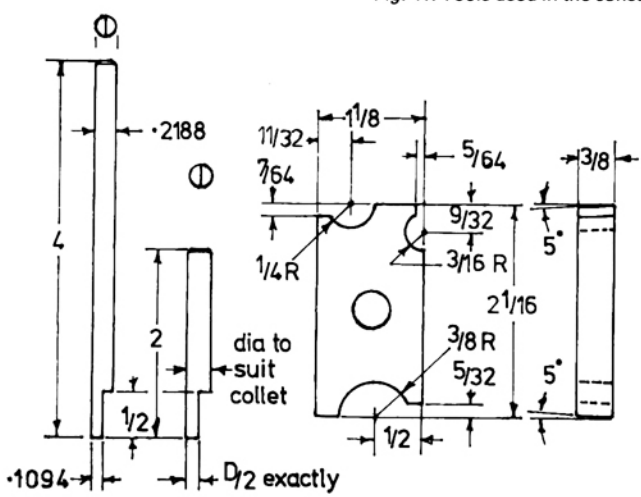


Fig. 41. Tools used in the construction.



centres or overhanging from the chuck and to put a rough hole down the middle. After parting off, re-chuck the tail end, with soft packing to avoid marking the work, in the four-jaw chuck and support the front end in the fixed steady. Set to run true, and here a "tenth thou" clock really is useful, not forgetting the fore and aft check to ensure parallelism.

Milling cutters with tapered shanks should be reground or sharpened supported by their shanks. For this a plain mandrel made from 1 in. dia. centreless ground round mild steel is easy to make. Again special care must be taken to ensure that the inner tapered bore is truly concentric with the outside. This type of mandrel can be used with the index plate or slide and rotate freely in the workhead, the cutter being guided by its own teeth in contact with a tooth guide in a manner which will be described in due course. The drawing shows a mandrel bored to receive at one end a No. 1 and a No. 2 Morse taper at the other, but of course other mandrels can be prepared to receive Brown and Sharpe or any other tapers. Unfortunately 1 in. diameter is not quite big enough to take No. 3 Morse so if much work of this size is to be done it would pay to bore out the workhead casting to 1⅛ in. dia. and to turn all the other parts to suit.

Milling cutters which have a central hole in them, such as plain cutters, side and face mills, circular saws and the like should, wherever possible, be ground from the cutter's own bore, turning and sliding on a close fitting dead mandrel. Only in this way, and even if the mandrel is eccentric, can absolute truth of the teeth with the centre hole be ensured. For this purpose a semi-expendable mandrel can be prepared from 1 in. dia. bright drawn stock–no need to use centreless ground–and turned down to suit the work in hand.

Made professionally of course, all these mandrels and spindles would be case-hardened and ground which would certainly improve their lives in the rather severe environment which inevitably exists in the vicinity of any grinding machine. But given care and in amateur use they will perform quite well if left soft and if they do wear they are not too difficult to replace.

CHAPTER 6

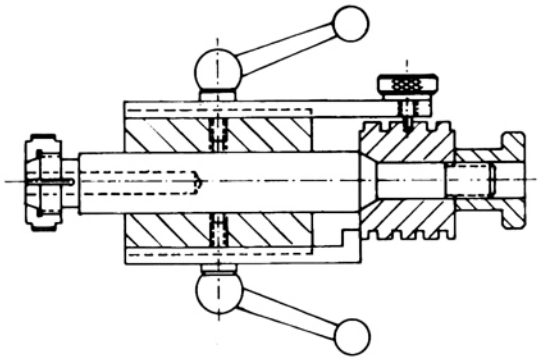
The Spiralling and Long Bed Attachments

The real purpose of the Quorn universal tool and cutter grinder was not however as far as the writer was concerned to grind "run of the mill" tools and cutters although it does this well enough. Its real "raison d'etre" was to find some way to make and resharpen the really tiny cutters down to 1/16 in. dia. which the writer has used in profusion to mill from the solid all the components of a 1/4 scale model B.R.M. V8 racing engine. Such tiny cutters cannot be sharpened by aligning the teeth against a rest–at least the writer cannot do it–the friction is too great and the slightest slip spells disaster. What was clearly wanted was some way of independently guiding the cutter so that the teeth had the right motion in relation to the grinding wheel, but which did not rely upon making contact with the teeth themselves. After various experiments the Spiralling Head, shown in Fig. 42 was evolved.

It comprises a long, relatively slender spindle which is free both to rotate and slide backwards and forwards in the workhead. At one end the spindle forms a spring chuck in which the cutter to be ground can be securely clamped. At the other end it carries a guide hob which has cut upon it a multiplicity of spiral grooves equalling in number the number of teeth in the cutter and having the same linear pitch. A guide pin carried in a fixed but adjustable guide bar engages the spiral grooves and an adjustable stop bar limits the movement.

With this apparatus once the cutter has been brought into the right relationship to the grinding wheel by using the other adjustments with which the machine is provided it is only necessary to rock the spindle back and forth by hand for it to have imparted to it at the same time the right spiral motion. When one tooth is finished by backing the hob out of engagement with the guide pin and re-engaging another start of thread the second and subsequent teeth can be ground in exact conformity with the first. Once set up the operation is extremely easy and can be performed almost blindfold, certainly there is no need to peer at the work under a magnifying glass and wonder how it is getting on. The only snag is that the hobs are difficult but not impossible to make. However, once made they last for ever and are cheaper than buying cutters at nearly a pound a time.

The main casting should be machined in exactly the same way and preferably with the same setting as the tool holder casting, particular care being taken over the longer 5/8 in. hole which, as previously explained, is the bearing for the spiralling spindle. The spindle itself is conveniently made from 5/8 in. diameter centreless ground rod mild steel–the same material from which the bar beds



SPIRALLING HEAD ASSEMBLY

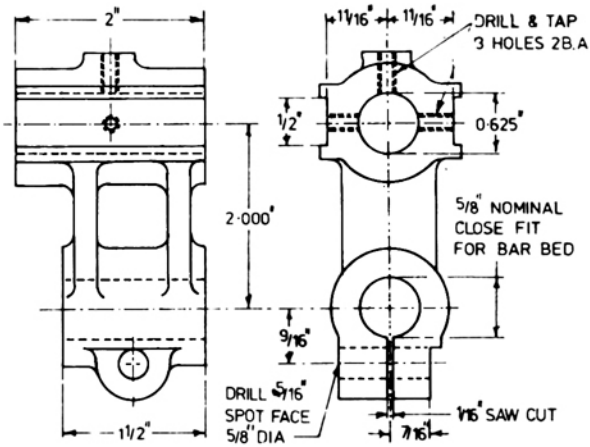


Fig. 42 HEAD BRACKET 1 OFF C.I.

are made. The spring chuck although simple will, if accurately made, hold cutters quite as accurately as a precision collet chuck. It is best turned at a single setting with one end of the bar held in a four-jaw chuck and the other supported in the fixed steady. The thread must be lathe cut as must be the matching thread in the closing nut. If the threads in either are drunken or eccentric they may force the spring jaws out of truth when the chuck is closed.

For work of this sort the writer does not attempt to produce fully-formed threads with rounded crests and roots. The extreme point of the V form internal and external screw cutting tools are just broken and the crests of the correspond-

ing threads left with a perceptible flat. This ensures that when a good fit is obtained the threads are really bearing on the flanks and not hanging on the crests and roots which is frequently mistaken for a good fit. The central hole must be finished to size with a boring tool but as it is rather long to finish to full depth this way it is permissible, once a true start has been made, to finish to full depth with a D bit or even an end mill used in lieu of a machine reamer. A hand reamer is not suitable as not only does it tend to follow an existing hole, which itself may or may not be true, but the "lead" will prevent the hole being brought to size for its full depth.

Since most of the writer's smaller cutters have either 1/4 in. or 3/8 in. plain or screwed shanks he has two spindles, one of each size, on which however the closing nut and the hobs are interchangeable. The rest of the components in Fig. 43 call for no special comment except to note that more ball handles are wanted, but that these unlike those used on the rotating base are drilled and tapped at 20 deg. to the axis.

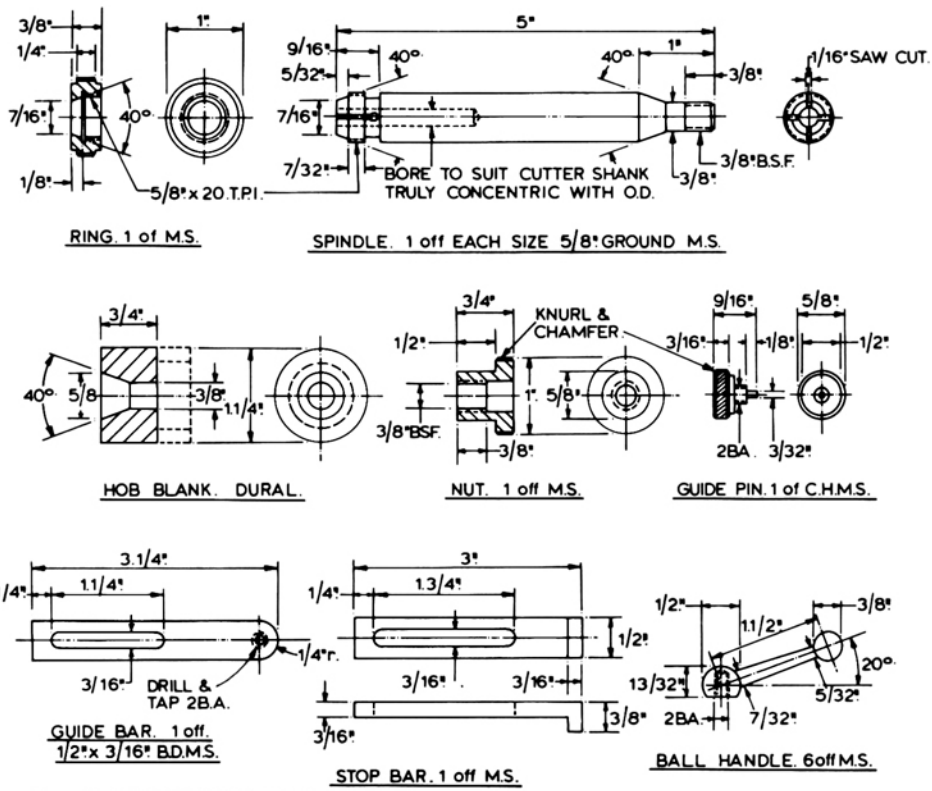


Fig. 43. SPIRALLING HEAD DETAIL.

Studs are screwed into the main casting for the ball handles locking the guide and stop bars and a short length of studding with a soft copper tip screwed into a third ball handle to provide a spindle lock. Once upon a time the writer always made 'proper' studs with a plain portion in the middle until he learnt from recent research work that studs screwed along their entire length and secured with 'Loctite' have a better fatigue resistance than plain shank studs driven to refusal in the ordinary way and are bettered only by high class waisted studs. It is an additional bonus that they are far easier to make!

This leaves us only with the problem of how to make the hobs. The difficulty here is that although most of the small end mills and slot drills that the writer has examined have a spiral angle, measured from the centre line of the cutter, of approximately 30 deg. it is not exactly so. Even with one make of cutter the spiral angle seems to vary somewhat with the range of sizes from 1/4 in. down to 1/16 in. dia. If the spiral angle really were 30 deg. it would be easy enough to calculate the pitch from the formula:-

$P = \pi D \tan \theta$

$= 5.4414 D$

where D is the cutter diameter and then to set up change wheels to cut this pitch. But a trial with the cutter held in the lathe chuck and a dial test indicator against one of the teeth may show that as the leadscrew is slowly revolved the reading does not remain constant. The only thing to do therefore is to 'fiddle' the gear train. Most lathes have change wheels with pairs of gears having very nearly the same number of teeth, for example 45 and 46, and 20 and 21. If they are used as a compound train the first will give a 2 per cent increase or decrease in pitch, depending on which is the driver. The second pair give a 5 per cent variation and by using them both together, that is 20 to 21 up followed by 46 to 45 down a 3 per cent variation is possible. For bigger differences it is probably better to change the largest wheel in the train to the next nearest size and to try corrections from the new train.

However, for a start here are the calculated pitches for an exact 30 deg. spiral angle and trains of gears which will cut them, near enough, with an 8 t.p.i. leadscrew.

Cutter Dia ins	Theoretical Pitch ins	Gear Train	Actual Pitch ins
1/16	0.340087	60 50 / 55 20	0.340909
3/32	0.510130	70 35 / 30 20	0.510416
1/8	0.680175	60 50 40 / 55 20 20	0.681818
5/32	0.850218	60 50 50 / 55 20 20	0.852278
3/16	1.020262	70 40 35 / 30 20 20	1.020833
7/32	1.190306	60 50 38 / 30 30 20	1.187500
1/4	1.360350	60 45 40 / 25 20 20	1.350000

Better trains than some of these can be found if other wheels are available, especially one with 34 teeth, but this is not usually to be found in an English screw-cutting lathe.

f course when one is making one's own cutters the pitch does not matter. Simply choose a pitch which is appropriate to the size of the cutter being made, say 3/8 in. pitch for a 1/16 in. dia. cutter. This can be very easily got by gearing up the leadscrew from the mandrel by 3:1, a 60 T wheel on the mandrel driving a 20 T wheel on the leadscrew, and will give a spiral angle of just over 27½ deg. Once made, the same hob can of course be repeatedly used for resharpening all the cutters made from it without any further worries about the pitch – it will always agree exactly.

Once a suitable train of gears has been found and set up, cutting the hob is simple enough. The same set-up as that shown in Fig. 8 for cutting the quick pitch thread in the vertical column can be used, but because the material is light alloy, much higher speeds and feeds can be used. Each hob should have as many starts of thread as the cutter has teeth. That is to say 2 for a slot mill, 3 for the 'throw away' type of cutter and 4 or 5 for a standard end mill. This can be done traversing the top-slide the requisite amount to cut the second and subsequent starts, but since all the recommended trains but two start with a 60 T wheel it is far easier, more reliable and more accurate to use this to index each start of thread by dis-engaging, counting the number of teeth and re-engaging the right angular displacement. But do not, under any circumstances, disengage either the leadscrew clutch, the saddle nut or the tumbler reverse when using these highly compound trains otherwise you will never pick up the thread again. Wind the saddle back by the leadscrew handle.

Other hobs can be made for special purposes. A particularly useful one has a straightforward 20 t.p.i. Vee form thread, engaging of course a Vee-pointed guide pin. With it plain shank cutters, even if hardened, can have threads ground on them to make them suitable for use in 'Clarkson' type self-locking collet chucks.

In certain operations, such for instance as backing off centre drills and certain types of spot facing drills, a limited endways motion must be given to the work while it is rotated. For this purpose the face cam shown in Fig. 43a can be employed which, engaging with the guide pin normally used with the spiralling hobs, gives the mandrel as it is turned a slight backwards and forwards movement, thus giving back-off to the work being ground. The steps at the end of each cam face prevent the mandrel, and the work, being turned through more than 180° and the face of another tooth, already ground, coming into inadvertent contact with the grinding wheel. Strictly there should be a cam face for each size of work and the curve should be a helix but the writer found that straight cuts, either filed or milled, of two different heights suited standard centre drills in the range from 1/8 in. to 3/8 in. diameter.

Although these are relatively straightforward examples it should be clear that any shape which can be produced in the master hob or guide cam can also be reproduced, by grinding, in hard material held in the mandrel chuck. This not only enormously increases the scope of the Quorn in regular cutter and tool grinding but also enables other work, such as grinding I.C. engine cams after hardening, to be undertaken.

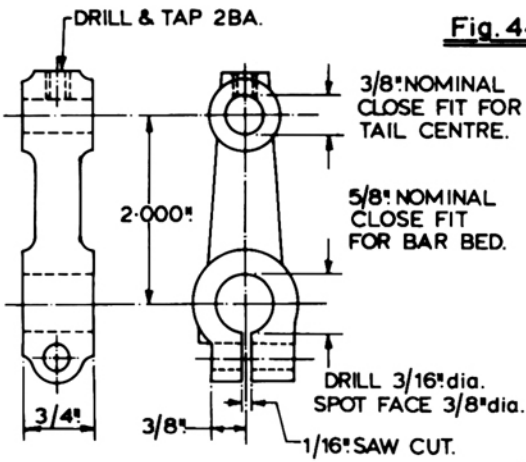
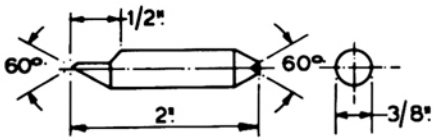


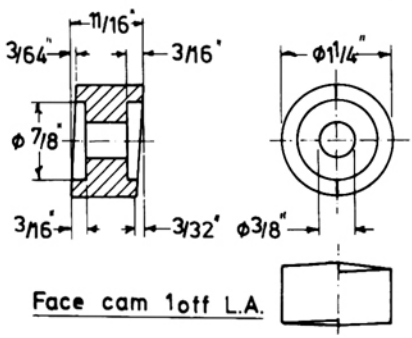
Fig. 44. TAILSTOCK.

TAILSTOCK. 1 off C.I.



TAIL CENTRE. S.S.& H.T.

Fig. 43a



Face cam 1off L.A.

Apart from miscellaneous nuts, screws and studs which have not been detailed, the only other item to complete the machine and its accessories is the tailstock which is used in conjunction with the long bar bed. This is particularly useful in dealing with long work such as taps and reamers which are best ground between centres. The tool holder bracket carries the Morse taper mandrel with an ordinary lathe centre in it, but either of the workheads could be used with any mandrel to suit the work in hand.

THE TAILSTOCK

The tailstock shown in Fig. 44 is a very simple casting, although as was explained before it is best machined at the same time and at the same setting as the other workheads so that the centre distance of the holes shall be as nearly as possible the same. Many small taps and reamers are too small to have a centre hole in them and are made therefore with male, that is pointed centres, left on their ends. To support them therefore by the tailstock a female centre is necessary and this may well be a half centre too, to allow clearance for the grinding wheel as it passes the end of the work.

CHAPTER 7

The Spindle and Driving Motor

Although a number of designs of high speed drilling and grinding spindles have from time to time been published in the *Model Engineer* and many of them could be used in conjunction with the Quorn tool and cutter grinder there has not been, as far as the writer is aware, a design for a modern high speed spindle running on preloaded angular contact bearings. Where running accuracy is important, and in a grinder it is paramount, spring-loading is often used. This removes all internal clearance from the bearings, promotes quiet running and allows relative expansion between the shaft and the housing without the spring-loading on the bearing being affected.

The design shown in Fig. 45 is an almost exact copy of a design recommended by the Hoffmann Mfg. Co. of Chelmsford, Essex (now R.P.H.) on page 102 of their Technical Manual and to whom all due acknowledgements are made. In this arrangement one bearing is firmly clamped endwise on both the inner and outer rings. The other bearing is also firmly clamped on the inner ring but the outer ring is pre-loaded by means of a spring-box. This enables the spring pressure to be carefully controlled and, providing the spring-box has a length approaching its diameter and is a close sliding fit in its housing, ensures that the spring pressure is applied squarely to the outer ring. Radial and/or axial loads can be carried by this arrangement, but axial loading should normally be in one direction only, that is, in the same direction as the force

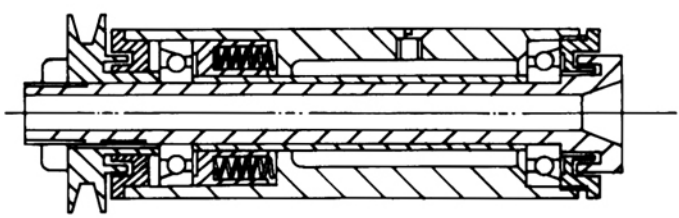


Fig. 45. SPINDLE ASSEMBLY.

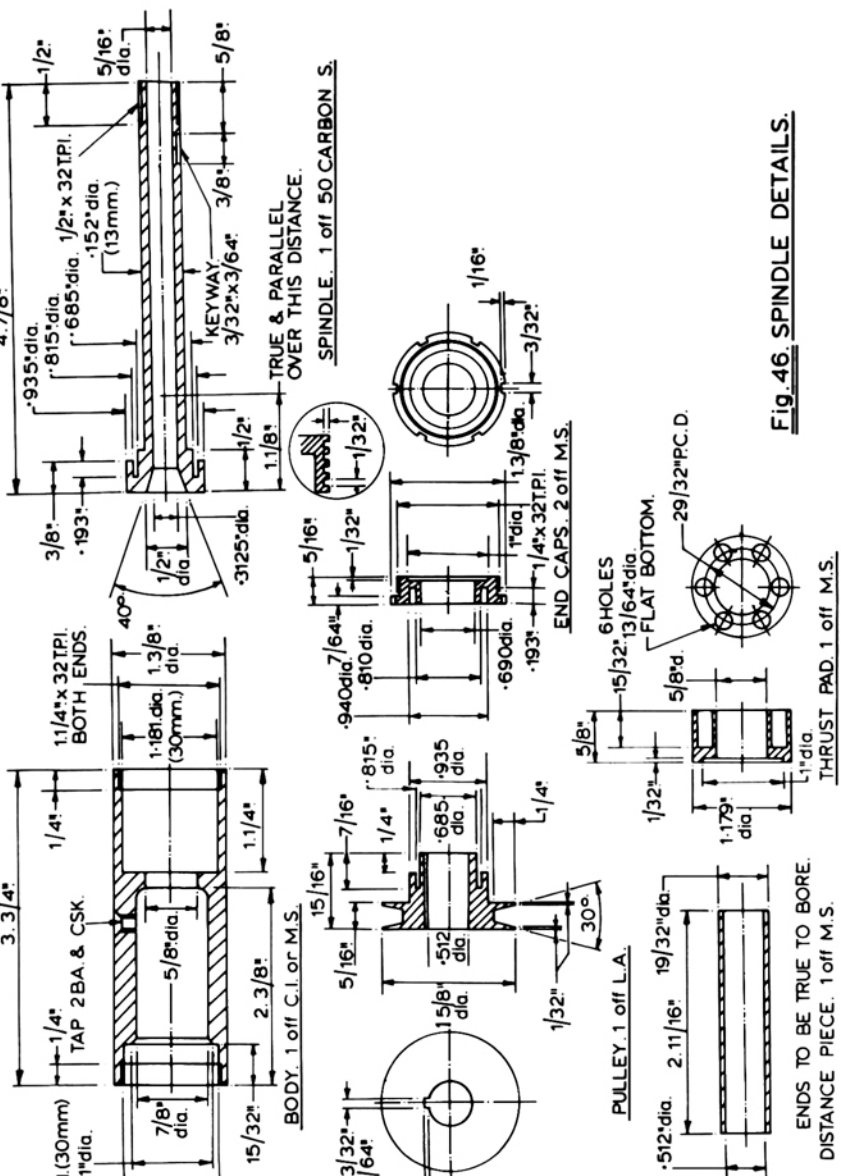


Fig.46. SPINDLE DETAILS.

exerted by the spring-box, not opposing it. The bearings at both ends are protected against the ingress of dust and grit by double labyrinth seals which cause no friction or heating, even after pr longed running at the highest speeds.

The only major departure that the writer has made from Messrs Hoffmann's design is to incorporate a hollow spindle with draw-bar and collet type nose. All grinding wheels are permanently mounted on arbors which have shanks to fit, they can therefore be rapidly and readily interchanged and once dressed to run true can be removed and replaced any number of times without redressing. This is of considerable advantage in tool and cutter grinding where more than one type of wheel may be necessary to complete the work.

Whether the spindle nose should be machined to accept regular 8 mm collects depends on the use the user intends to make of it and the other equipment of this size that he may have. Because the complete wheelhead is self-contained and removable, it can be used on the lathe, milling machine, planer or shaper as a toolpost grinder or light drilling or milling attachment – complete with built-in height adjustment. In this role small drills and cutters can be held in regular split collets. But if collets are not in use or there is no intention of using the spindle in any other role the dimensions shown in the drawings are easier to produce with Imperial tools although the resultant spindle will not accept any regular 8 mm collets. Of course this still does not prevent tools and chucks, even collets, being made to fit the spindle nose, so you pays your money and you takes your choice.

Since the quality of the work turned out by any grinding machine depends, above all else, on the quality of the wheel spindle bearings, the utmost care in the construction of the spindle assembly will pay dividends later. The body shown in detail in Fig. 46 is best made from mild steel bar or thick walled tube

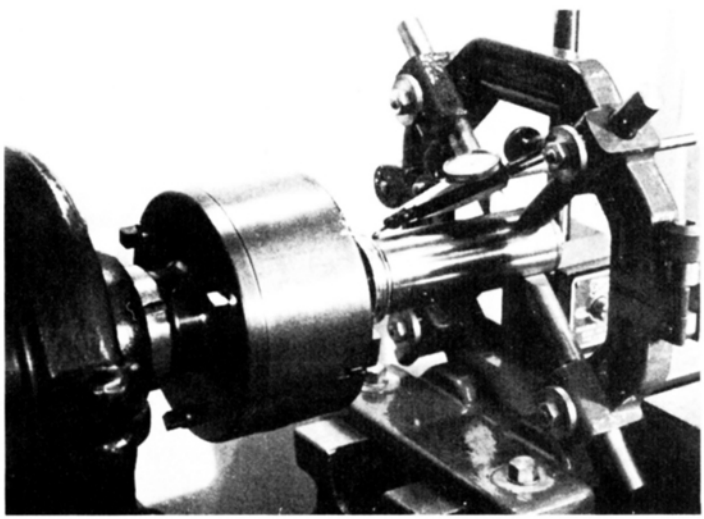


Fig. 47. Setting work true in a 4-jaw chuck and fixed steady.

although if care is taken with the threads cast iron can be used. As it is absolutely essential that the bearing housings at both ends are truly in line with one another it is probably best to rough bore th interior to get rid of any residual stress in the metal, particularly if it is bright drawn, and then to turn and preferably lap the external diameter to finished dimensions. In this state, as has already been suggested, it can be used as a mandrel for aligning the wheelhead bracket prior to machining and as a datum for all subsequent machining operations. These should be conducted with one end of the body held in a 4-jaw chuck and set to run dead true and with the other end supported in a fixed steady. Here it is again vitally important to set the fixed steady dead true to the lathe axis so use a dial test indicator to ensure that the body is neither pointing up nor down nor back to front. This type of test is shown in Fig. 47 where the entire spindle has been set up for the purpose of boring the collet seating. Although it is not good practice to use the bearings themselves to size the housing into which they will eventually be fitted, in the case of the A13 magneto type ball journal bearings which will be used in the spindle for the Quorn the outer rings are readily removable. One should therefore be removed and after carefully repacking the remainder of the race may be used as a gauge for sizing the internal diameter of the housing. After use it must be scrupulously cleaned and reunited with its inner ring and ball race to await final assembly. Both outer rings should be made a sliding fit, not a press or force fit and it is particularly important that the outer ring of the bearing at the spring-box end should be able to slide freely under the influence of the spring pressure. The extended bore for the spring-box itself should also be made as smooth and parallel as possible so that the box too can slide freely but without any shake or wobble. The shoulder in the shorter housing and against which the outer ring of one bearing is clamped must be truly faced and chamfered as shown to obviate any possibility of contact with the ball race or its cage. The screw threads to secure the end covers must be lathe cut, not only to ensure their truth but because no tap of this size exists or ever will! The choice of pitch is arbitrary, any fine thread will do, but 32 T.P.I. is convenient with an 8 T.P.I. lead screw because it means that the leadscrew half-nut can be dropped in anywhere. The other dimensions are "air fits" and not critical.

The spring-box is a straightforward turning job except that the 30 mm. diameter must be a close sliding fit but without friction in the housing and that the end face which bears against the outer ring of the pre-loaded bearing must be dead at right angles to it. Machine these two features therefore at a single setting. The size of spring given and the depth of hole to accommodate it is calculated to give a pre-load of 4 lb. force, but as small springs are liable to some variation in their strength it is prudent to drill the $^{3}/_{16}$ in. holes rather less deeply than shown and to adjust their depth when, after assembly, the actual preload can be measured.

After the bearing housings, the spindle is the next most important item in obtaining a precision bearing assembly. Because of the central hole for the draw-spindle it is a bit on the flimsy side and deserves to be made of something better than free cutting mild steel. "50 carbon" or "machinery" steel is quite a bit stronger than mild steel and not a lot

more difficult to machine. High tensile steel from a high tensile steel bolt or a large cap screw would be ideal and again not all that difficult to machine, that is if your tools are ground to the pr per rake and clearance angles which they will be as soon as you have finished your Quorn. The first operation is undoubtedly to put a letter "N" size hole right through the middle, preferably from one end only if you have a drill long enough, but if not from both ends. The snag of drilling from both ends is that the holes rarely meet in the middle and the resulting step, which will interfere with the passage of the draw-bolt, is difficult to get rid of. Centre both ends of the hole wherever they may be at 60 deg. included angle and do all the rest of the work between centres. And do not trust your live centre to be true for this class of work. It should be soft so skim it true and leave it in position until all turning work is finished. The main body of the shaft must be an interference fit in the inner rings of both races. For those who have accurate micrometers and can use them the size recommended by the manufacturers of the bearings is max. 0.5120 in., min. 0.5117 in. diameter.

If you cannot work to these limits and it really needs grinding or lapping to achieve them, make the inner rings a stiff push fit but on no account so tight that it needs a press or vice to get them on. More ball and roller bearings fail through excessively tight fitting, which crowds the races, than ever fail through legitimate wear and tear. Trepanning the recess for the outer labyrinth seal may prove rather difficult and would certainly need a special tool. It is permissible therefore to make a separate outer ring, 0.935 in. o.d., 0.815 in. i.d., and 3/8 in. long and to press or "Loctite" it in place over the spindle turned down to suit. The thread again is arbitrary, 13 mm. by 32 T.P.I. is no known size but convenient to cut on an English lathe. The problem of getting the bore of a spindle to run true is a perennial one and has been dealt with many times in *Model Engineer*. Although fitted plugs, boring in a fixed steady and so on have their merits, in the writer's opinion there is only one way to ensure that the bore runs dead true and that is to bore it after final assembly with the spindle running in its own bearings. This practice is adopted even by precision machine tool makers who have facilities for accurate work far beyond those of even the well equipped amateur. So leave the bore as it is for the time being and until the spindle has been finally assembled.

The spacer, although it looks simple, is in fact quite critical. The bore needs to be straight and parallel and a close fit on the spindle with the ends faced truly square to it. Otherwise when the lock-nut is clamped up tight, as it should be, the spindle may be bent or the bearings thrown out of alignment, either of which will be detrimental to the running of the spindle. Remember that here we are looking for tenths of a thou which is all that makes the difference between a precision spindle and one that just runs.

The pulley, lock-nut and end covers are straightforward turning jobs, threads cut of course to match the mating parts. To put in the rather deep grooves for the labyrinth seals which cannot very well be built up it is worth while to make, from 1 in. dia. silver steel, a double ended hollow end mill. If one end is 0.940 in. o.d. by 0.1810 in. i.d. and the other 0.815 in. o.d. by 0.685 in. i.d. it will do both end covers and the pulley. Incidentally these rather odd sizes are 2½ thou up and down on standard fractional sizes and intended to give

0.005 in. clearance in the labyrinth seals.

After all the parts have been washed scrupulously clean and left to drain, not wiped with rags, the spindle may be assembled and tested for preload. The body should be supported with the spindle nose down and weights or a spring balance applied by a cord through the central hole until the tension of the preloading springs is just overcome and the spindle moves forward. The recommended pre-loading for this size of bearing is between 4 and 12 lb. force. For light work there is little point in working to the higher limit and the writer set his to 4 lbf which seems to work very well in practice. Adjustment is made of course by deepening the holes in the springbox, but make sure that all the holes are of the same depth and the springs of equal free length so that the pressure on the outer ring is uniform.

After the spindle is finally assembled and has preferably been run in a bit it is time to turn attention again to the all important bore for the collet chucks. If the spindle has been bored letter 'N' size and the drill has not cut oversize there is 13 thou on diameter to come to clean it up to 8 mm. To support the spindle in its own bearing for this operation the set-up shown in Fig. 48 may be used. The tail of the spindle is held, by the flats on the lock nut, in a 3-jaw and the front supported, by the body, in a fixed steady.

It is imperative that the work is set true to the lathe centres before machining begins. Nearest the chuck the body will wobble unless the spindle is running true but how can this possibly be achieved with an ordinary hexagon nut held in a 3-jaw chuck? The answer is simple if you take the advice given to me many years ago by no less an authority than the late Cmdr. Barker. That was to take the chuck off its backplate and to turn $^{1}/_{32}$ in. off the register. Open out the holes in the backplate a similar amount

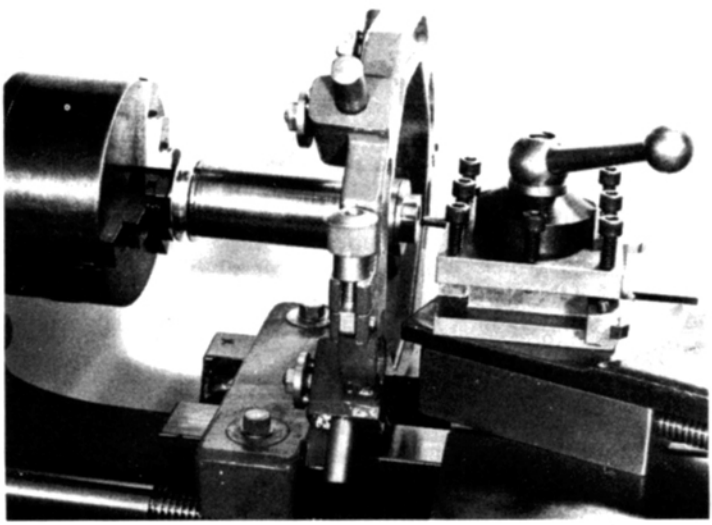


Fig. 48. Final boring of the spindle nose.

and put it all back again. You now have a chuck which, like the 'Griptru', can be set to run true holding work of any diameter regardless of wear in the jaws or the scroll and contrary to all belief the body does not slip on the backplate, even when parting off 3 in. dia. round steel with auto-feed! *

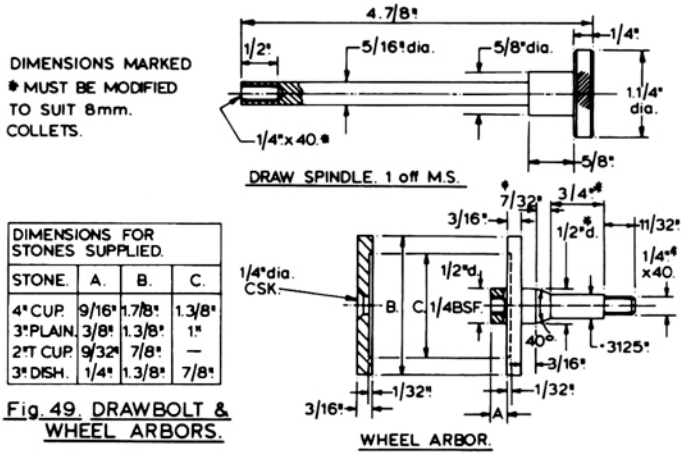
However, to return to our spindle, once all movement of the body at the chuck end has been eliminated, either by the means described or, if you are more conventional, by using a 4-jaw chuck, the body must be set parallel to the lathe axis by traversing a dial test indicator mounted on the saddle of the lathe. Two separate checks must be made, one for up and down and one for fore and aft. It will pay to get this really right and it is here that having a body which is truly round and parallel is an advantage. The body can, of course, be quite firmly gripped in the jaws of the fixed steady since it does not rotate. The bore can now be opened up, as in Fig. 48, with a sharp boring tool to a depth of at least 1⅛ in. It can be sized with a reamer or 'D' bit, but do not be tempted to use the reamer straight into the rough bored hole, it will certainly follow any eccentricity there may be. The rest of the holes can however by cleared by a 5/16 in. reamer or twist drill to pass the draw-bolt. The 40 deg. seating for the collets must also be lathe turned using marking blue and a standard collet to check the accuracy of the taper. For jobs like this the writer allows himself a wee scrape with a sharp graver to spread the area of the marking, but not of course to alter the angle of the taper. With care you should now have a seating for the chucks and arbors running true to one tenth of a thou or better, but you will never want to dismantle the spindle again because if you do you will never get it back to the same standard of accuracy.

The draw-bolt and a typical wheel mounting arbor are shown in Fig. 49. The draw-bolt needs to be made of something better than free-cutting mild steel, mainly to save wear on the threads which engage the shanks of the collets and arbors. Case hardening fine threads is not good practice, the threads tend to become through hardened and fracture under load. Again material from a high tensile bolt or cap screw is ideal and the head provides a good starting point for the knurled hand wheel. Once upon a time the writer used to turn arbors such as that shown in Fig. 49 from solid bar, which produced more swarf than work. Now he parts a disc from a large bar and 'Loctites' it to an arbor turned from ½ in. bar, skimming true after the 'Loctite' has hardened. The disc should be large enough to give adequate support to the wheel. Most wheels have a soft paper disc stuck to them and the metal discs between which the wheel is clamped should have a comparable diameter. The dimensions for the shank of the arbor must of course match those to which the spindle nose has been bored, be it to Imperial dimensions or to suit the particular make of collet in use.

MOTOR

To complete the machine a driving motor is required. Here there is a wide choice but an urgent word of warning must be given. ON NO ACCOUNT WHATEVER use a universal A.C./D.C. or series wound D.C. motor. Such motors race uncontrollably when they have no

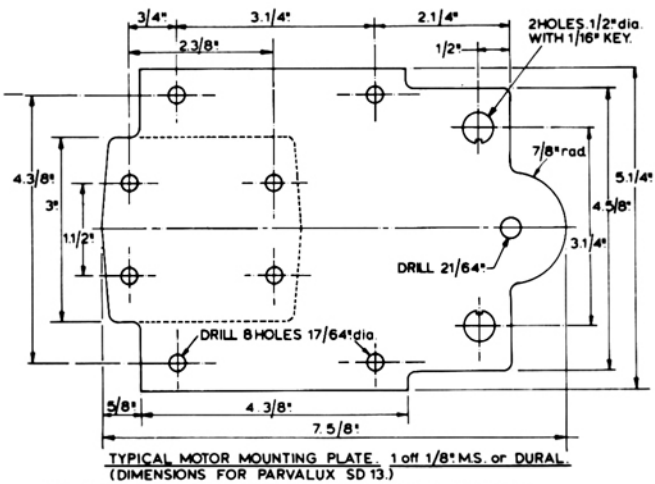
* This procedure cannot be adopted with some modern chucks which do not have separate backplates.



DIMENSIONS FOR STONES SUPPLIED.			
STONE.	A.	B.	C.
4" CUP.	9/16"	1.7/8"	1.3/8"
3" PLAIN.	3/8"	1.3/8"	1"
2"T CUP.	9/32"	7/8"	—
3" DISH.	1/4"	1.3/8"	7/8"

Fig. 49. DRAWBOLT & WHEEL ARBORS.

load and the writer has timed a popular spin-dryer motor doing 14,000 r.p.m. running light. All grinding wheels carry, by law, a label giving their maximum safe speed and this speed must NEVER BE EXCEEDED, regardless of whether the wheel is cutting or not. To gear down the wheel from the motor, as was done on, a cutter grinder exhibited at a recent Model Engineer Exhibition, while it may safeguard the wheel from overspeeding when it is running light, is not satisfactory because as soon as the load comes on the wheel the motor will slow down



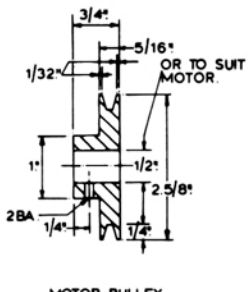


Fig. 50. Mk.I. MOTOR MOUNTING PLATE & PULLEY.

quite considerably, probably to something like half speed before giving its full rated output. Under these conditions wheel wear will be excessive and no grinder can be expected to do good work.

So an A.C. induction or shunt wound D.C. motor MUST be used because these motors do not race when running light and drop very little speed when the load comes on. For convenience it is better to choose a high speed motor, 2,800 r.p.m. rather than 1,400 r.p.m. in the case of a 50 cycle A.C. motor or 4,000 r.p.m. in the case of a shunt wound D.C. motor, because not only is the frame size and the cost less for a given power but the driving pulley on the motor shaft need not be excessively large. The actual power needed depends on the work to be done. Although the writer's own machine was for some two years equipped with a 1/12 H.P. 2,800 r.p.m. motor and survived grinding all the cutters brought to it during two Model Engineer Exhibitions, it was in fact only used as a temporary expedient to get the machine going and is rather small for the job. After studying all the catalogues, the writer came to the conclusion that a S.D.13, 2,800 r.p.m. 1/6 H.P. single phase, permanent capacitor motor manufactured by Messrs. Parvalux Electric Motors Ltd., of Bournemouth, England was a good buy and in keeping in size and weight with the rest of the machine.

The principal difference between the Mk I and Mk II wheelheads is the method of mounting the driving motor. By using a flat adapter plate bolted to the machined end of the Mk I wheelhead bracket casting, any suitable motor can be readily mounted on the Quorn grinder, but the plate shown in Fig. 50 is dimensioned to suit the Parvalux motor. An extension to the plate carries the

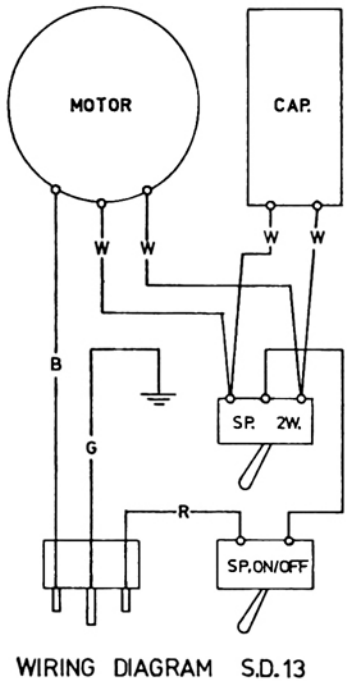


Fig. 51. Two-switch wiring diagram.

capacitor in a single mounting hole and two switches. One is a simple on/off switch but the other reverses the direction of rotation of the motor. This is very convenient in cutter grinding because the rotation of the wheel must always be in a direction to hold the work against the tooth rest and never to lift it up, which could be disastrous to both work and wheel. A wiring diagram to suit the colour coding of the Parvalux motor is given in Fig. 51 and by suitably connecting the white leads to the single pole two-way switch the periphery of the grinding wheel nearest to you can be arranged to run in the same direction as

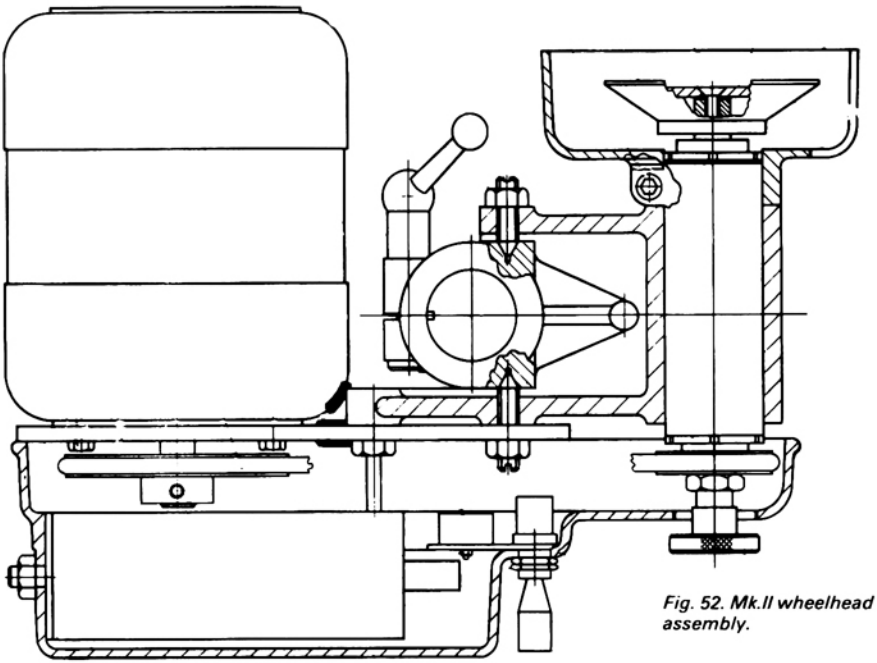


Fig. 52. Mk.II wheelhead assembly.

you push the dolly of the tumbler switch–an elegant detail in ergonomic design! Unless the machine is to be permanently mounted, a wander lead with a 3-pin plug is probably the best way of supplying the machine with power, but even if permanently mounted there should be a fairly long lead to the motor to allow for all the movements of the wheelhead. In both cases the machine should be earthed through the third wire.

An alternative circuit employing only one single pole, two way, centre off switch which can also be wired up so that the wheel revolves in the direction in which the switch is pushed is used in the Mk II wheelhead and can also be used on the Mk I.

The difference in the method of mounting the Mk II motor wheelhead is shown in Fig. 52, which being adjustable for centre distance enables a fixed length rather than an elastic belt to be used. The motor plate shown in Fig. 53 is slotted and drilled to suit an end-mounted Parvalux SD 13 motor. Although such motors are listed in the maker's catalogue they are not always available from stock, but the much more widely available foot-mounted motor can be readily converted. Dismantle the motor by removing the four through bolts and saw the feet off the end covers, making good the circular periphery by careful filing and repainting. Cored holes in the end covers already exist for end-mounting and those at the shaft end

can be tapped 2 B.A. External wiring is reduced to minimum if the stator is reversed and the motor leads brought out at the shaft end rather than the blind end, so drill an additional hole in this cover and refit the rubber grommet. At the same time reduce the length of the motor spindle by 1 in. to clear the capacitor which will be mounted in the belt guard. On re-assembly make sure that the exhaust ducts in the end covers are pointing towards the grinding spindle and not away from it so that dust is blown out instead of being sucked in!

The belt guard needs little machining. Dress the flat face so that it sits firmly on the motor plate without rocking and drill the various holes for mounting the capacitor, switch, securing screws, cable lead (which must be fitted with a grommet) and clearance hole for the end of the grinding spindle and its draw-bolt. Note that the securing screws enter tapped holes in two of the set screws securing the motor plate to the main casting so that when the motor plate is shifted to adjust belt tension the relative position of the belt guard to the grinding spindle remains unchanged. Wiring up, Fig. 54, is rather tight so needs doing with care. In particular the motor leads where they pass through the motor plate must be fitted with a grommet and taped up so that there is no possibility of them coming into contact with the driving belt.

The speed at which the spindle should run will be set by the SLOWEST wheel which will ever be used. In the writer's case this is a 3½ in. saucer wheel which has a maximum speed of 4,800 r.p.m. The pulley shown in Fig. 50 gives the spindle this speed and although some of the other wheels in use can be run faster than this, up to 6,200 r.p.m. in fact, it is better to be safe than sorry. The driving belt can be either 3/16 in. round black

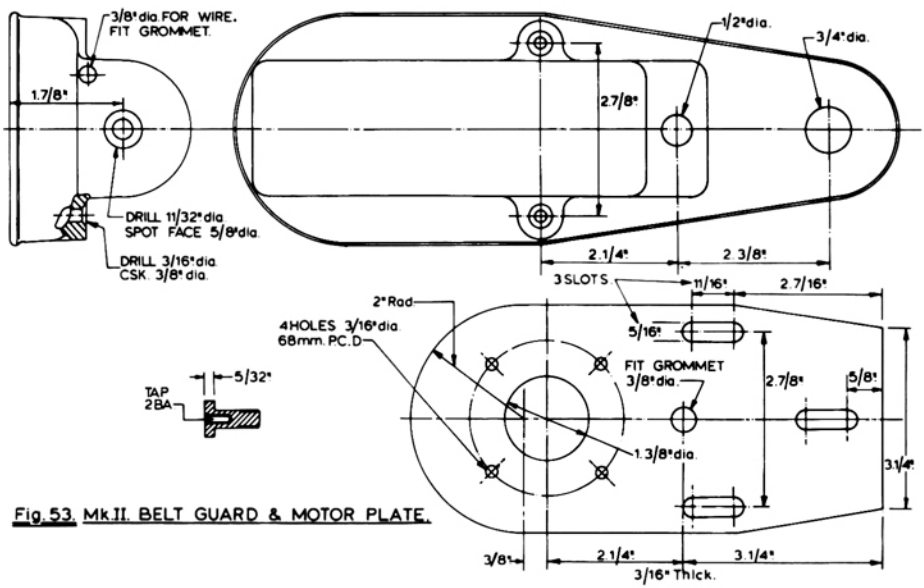


Fig. 53. Mk.II. BELT GUARD & MOTOR PLATE.

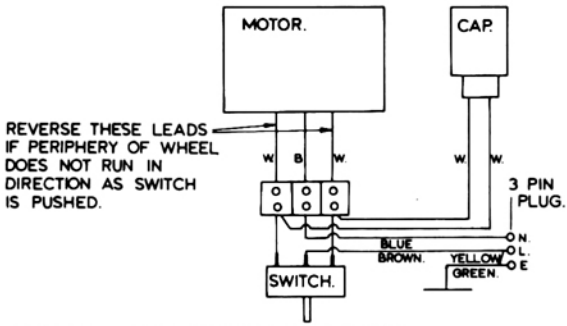


Fig.54. SINGLE SWITCH WIRING.

plastic or hollow polyurethane belting. The former has the advantage that it is easy to make jointless by heat-joining the ends and is equally easy to repair if it breaks. It runs very smoothly over the pulleys, but is at about the limit of its capacity when transmitting 1/6th H.P. at 4,800 r.p.m. Polyurethane is a newer product, and although it can be joined by heat if desired it is normally joined by a special aluminium connector which snaps inside the hollow bore of the belt. It has much less stretch than black plastic and an excellent co-efficient of friction which gives a very positive drive with a minimum of belt tension. The lightweight fastener, if used, gives a slight jolt as it passes round the pulleys, but the effect of this on the work is not noticeable.

The wheel, guard Fig. 55, can be fitted to either machine and its use is strongly recommended as it not only helps to keep things clean but complies with safety regulations. It needs little machining and clamps to the nose of the spindle housing with a single 1/4 in. BSF. cap screw.

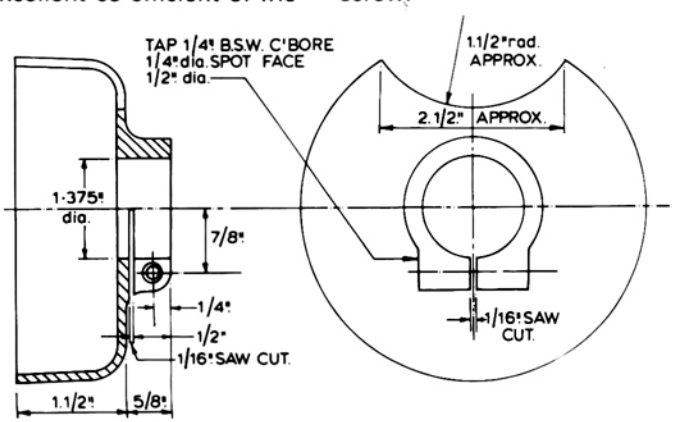


Fig. 55. WHEELGUARD.

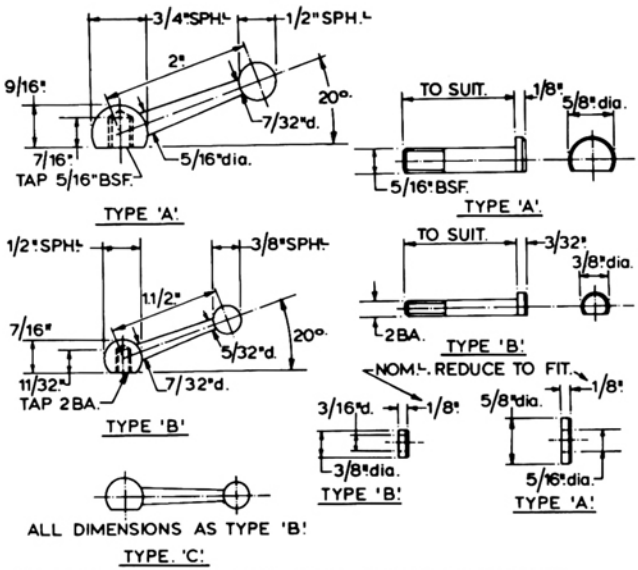


Fig. 56. BALL HANDLES, LOCK BOLTS & WASHERS.

also leave a shank of the right diameter which would serve as a witness for the final turning operations. By a miracle of foresight in design only three sizes of form tool are needed because the small balls on the large handles are the same size as the large balls on the small handles! In fact all three are incorporated in a single tool made from an old flat file softened and then machined to shape. Since the work produced by a form tool can be no better than the tool itself the

Fig. 57. Parting off short pieces from a long bar in the lathe.

CHAPTER 8

Ball Handles and Painting

The immediate comment of everyone who sees the machine for the first time is "Look at all those ball-handles!". They are there for a purpose. It suddenly occurred to the writer, after using his trusted and well-beloved 3½ in. Drummond lathe for nearly a quarter of a century, that whereas the tailstock could be moved and locked without using any tools at all, it took three separate spanners of different sizes to set a tool in the toolholder, bring it to height and set the top-slide. When, therefore, he came to build his Dore-Westbury light vertical milling machine he decided that it should be built so that it could be operated without the use of any spanners whatsoever. It works, and the saving in time and frustration in looking for spanners which one has only just put down but which have nevertheless mysteriously disappeared has to be experienced to be appreciated. In the Quorn tool and cutter grinder a large number of adjustments are necessary, indeed a larger part of the time in sharpening a single cutter is spent in setting it up than in the actual grinding, and all of them can be made without the use of a single key spanner.

As 9 of the larger size and 8 of the smaller size of ball handle shown in Fig. 56 will be required, it pays to set up to mass produce them and do the whole lot at a single sitting. The first operation is to cut up the requisite number of blanks from ¾ in. and ½ in. dia. b.d.f.c. mild steel 2⅝ in. and 1 15/16 in. long respectively. It pays to get the blanks to rule size for length because they can then be machined without any further measurement. Owners of power hacksaw machines will no doubt cut up their bars this way, but as the writer does not own such a machine and hates hard work he cuts up long bars in the lathe. The set up is shown in Fig. 57. The tailstock is removed and a fixed steady put in its place. The length of bar which can be worked upon this way is only limited by the size of the workshop and short pieces can be cut off the end near to the chuck with absolute security and freedom from chatter. With an inverted parting tool in the back tool-holder, the lathe in open gear and the auto cross-feed in, the cutting off time is shorter than a low power saw would do it.

After all the blanks are prepared, the next operation is to form the balls each end. Although a number of spherical turning attachments have, from time to time, been described in *Model Engineer* and of them that described by Mr. Radford is in the writer's opinion far and away the best, they do present clearance problems if, as in the present case, over 80 per cent of the periphery of the ball is to be machined at a single setting. The writer therefore decided to make a form tool which would not only form the complete ball in a single operation but would

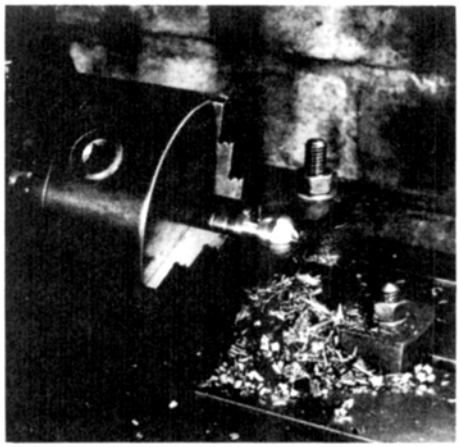


Fig. 58. Form turning 3/4 in. dia. balls.

various radii are best produced by internal turning with the work clamped off centre on the lathe faceplate. This not only ensures that they are of a good shape but by setting the top-slide over to an angle of 5 deg. gives accurate control over the clearance angle. The clearance angles on the flat faces are most accurately put in by milling.

After hardening and tempering to a light straw colour, the tool is used upside down on the back toolpost as in Fig. 58. This may appear to be a rather formidable operation and although one can start with the lathe in open gear, as the width of cut increases it is necessary to "change down" finishing in low back gear in order to provide the torque necessary to sustain a cut over 1 in. wide. In Fig. 58 the witness mark of the original bar diameter is just about to disappear—when it has gone the ball is to size and the cut is stopped. The work needs to be very firmly held in the chuck: close examination of Fig. 58 will show that it has, in fact, slipped, but this is no matter because this part of the blank will be completely turned away in a subsequent operation.

When all the blanks have been dealt with the next operation is to reverse them in the chuck and rough down about 3/4 in. length to 1/2 in., again holding the diameter to rule sizes. The 1/2 in. balls can then be form turned by the same procedure and while the tool is in place the large balls on the small blanks produced at the same setting. Finally the small balls on the small blanks, by which time the lathe will have acquired an impressive pile of broad curly swarf.

The worst is now over and for the next operation the immature ball levers are held by the larger ends in the 3-jaw chuck, with a piece of soft packing to prevent the jaws marking the finished surface, and with the tail ends supported in a female running centre. "Tubal Cain" in his advice on Workshop Equipment and Materials classified a running centre as essential for those who are able to afford it. This is true, but they are also very easy

Fig. 59. Work supported in a female running centre.

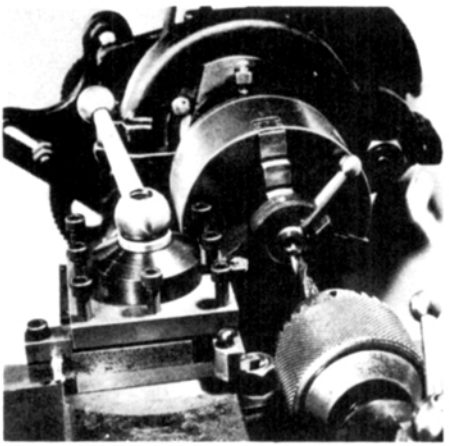


Fig. 60. Facing, drilling and tapping ball handles.

to make and one of the few examples of the correct use of a single angular contact ball bearing without preload. The writer's running centre was made many years ago and has interchangeable male and female centres. Supported this way the central shank of the ball levers can be readily turned down to size and once the top-slide has been set to pick up the witness marks to both ends, the rest of the levers can be turned without further measurement.

The final operation is to drill and tap the screwed hole. Here it is important that the 20 deg. offset angle shown in the drawings is adhered to, otherwise the handles will foul one another when they are fitted to the machine. Unfortunately the jaws of the average 3-jaw chuck are not long enough to allow the levers to be held by the larger ball for drilling and tapping and for the shanks to be set back 20 deg. before they come into contact with the chuck face. A piece of tube was therefore chucked and bored out to receive the ball ends with a cut-away to clear the shanks. Although it was also split on one side the closing pressure of the chuck jaws was not sufficient to hold the levers securely enough for drilling and facing. Therefore a stout "C" ring with two Allen screws was loosely fitted around the tube and when the grub screws were tightened held everything with a remarkable degree of firmness. Incidentally, 20 deg. of offset angle is achieved when one ball end is 0.809 in. higher than the other, which you can check by using the leadscrew micrometer index and a dial test indicator, but an 0.8 in. rule setting will do! If blind holes are to be drilled and tapped, and the writer strongly recommends them on the grounds of neatness and absence of cut fingers, the depth of the hole must be carefully gauged to be as deep as possible but without breaking through and tapped to its full depth with a plug tap. The final operation is shown in Fig. 60 and a group of components in various stages of machining, together with the special tools used in Fig. 61.

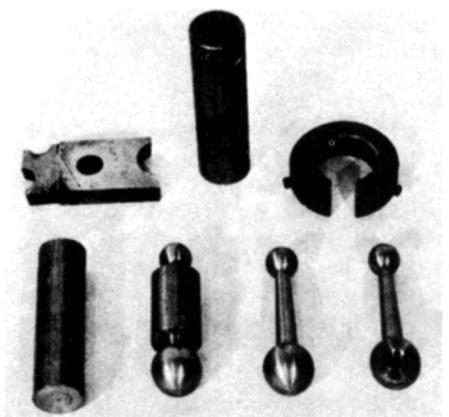


Fig. 61. Stages in machining and special tools.

When fitting the ball handles to the machine it is important that they come, in the locked position, to the angles shown in the various drawings. Each is fitted over a distance washer of 1/8 in. nominal thickness which is intended to be faced down to suit its individual ball lever. Bearing in mind that 5/16 in. BSF is 22 t.p.i. 0.011 in. off will move the ball lever one quarter of a turn. If you overdo it make another washer or better still make some spares in the first place! Dimensions for the overall length of the lock bolts are not given because it will depend on how much is faced off each casting to provide a seating for the distance washer. So measure up each casting after it has been machined and add 9/16 in. to it for the larger and 7/16 in. for the smaller to get the shank lengths of the lock bolts. As a final check on assembly, remove the distance washer and make sure that each ball handle has about 1/2 a turn free movement from the normal locked position before it becomes thread bound.

PAINTING

After a trial assembly of the machine the writer believes in stripping it down again and spending some time in finishing the castings. Although he has received many congratulations on their quality, and they were good, the real finish comes from painstaking "bringing forward", stopping and rubbing down. So pay a visit to your local D.I.Y. dealer in motoring accessories and arm yourself with some of the modern products which are designed to bring bent, battered and rusted tin ware to a state of impeccable finish. Knock the worst lumps off the castings with a rough file and give them a good scrubbing in the kitchen sink with hot, strong detergent. Rinse in hot, clean water and let them dry naturally.

Never mind if the shiny bits show a film of red, it only shows that they are clean and will come off on the first contact with an oily rag – which is the last thing that should be used at this stage. Now mix up one of the modern polymer resins with its approximate hardener and filler, "Isopon", "Cataloy" or the like and knife it on the casting either with a putty knife or an old hacksaw blade with the teeth ground off. The aim here is not only to fill any gaps or blowholes, which it does excellently, but to "bring forward" the entire surface to a level at least as high as the worst excrescence on the casting. So put on plenty, it is much easier to file off excess than to have to do it again, but you will have to work quickly and firmly because in 20 minutes or so the stuff will be hard enough to file.

Use a coarse file to reshape the body of the casting. Don't niggle over detail or worry about surface finish at this stage; plenty of time for that later. Hold the casting up to the light at various angles and see if there are any major bumps, hollows or unevennesses which could be improved. Stop filing when bright metal shows and if necessary apply more filler after another scrubbing and hot water rinse. Remember that this is your last chance to remove all signs of their foundry origin; if there are any bumps or hollows left they will be even more obvious as the surface finish improves. When satisfied give two coats of cellulose brushing primer. Stir the tin well to get the goodness up from the bottom, it's the body you want, not the solvent. Apply each coat as thickly as you can short of getting "runs" but even these do not matter at this stage because they can be rubbed down afterwards,

but it is tedious and a good painter does not make unnecessary work for himself – there is enough of that anyway. The secret of brushing cellulose paint is to get it on as quickly as possible and then to leave it alone. They cannot be brushed out and worked like the slower drying oil paints, but the thicker quick drying film will even out all but the worst unevennesses and brush marks.

Let them dry overnight and proceed once more to the kitchen sink armed with some wet-and-dry paper and a bowl of warm water with a spot of detergent in it. Fold the paper in half, hold it between finger and thumb and rub down with finger pressure alone. When bright spots or the colour of the stopping begins to appear, stop rubbing down, rinse the casting in clean water, let it dry and survey your handiwork. In some places at this stage the rubbing down will have produced a uniform matt surface, but there will inevitably be many others where the paint surface is untouched. These must now be "brought forward" again but this time with cellulose putty. Unlike the stopping this must be applied thinly because it shrinks on drying. Rub down the areas that have been puttied and after another wash and rinse apply another coat of primer. After the next rub down the matt area will be much larger but you will begin to notice lots of quite tiny areas which have not been cut back. The worst ones can be dealt with by more putty, but the smaller ones will disappear as more coats are applied and rubbed down.

At this stage the castings should begin to exhibit a glassy smoothness when they are wet and show an even reflection of light in every direction. Just how far you go depends on your enthusiasm and patience. The writer usually gets the bit between his teeth at this stage and decides that this time he is going to make a proper job of it and that one more coat will bring him that nearer to perfection! The last stages are the easiest of all. Two coats of under-body colour lightly rubbed down and a top coat of matt or gloss finish as you prefer. But the quality of the top coat will depend entirely on what is underneath it and no amount of brushing or spraying can improve it. At all stages there is no need to bother if paint gets on the parts that are to be left bright, nor in monochrome work to try to cut in an edge, excess paint can easily be removed after it has hardened with a sharp knife or scraper.

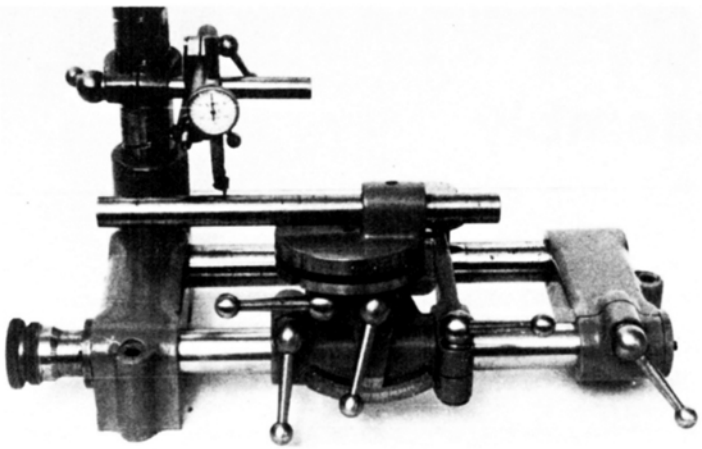


Fig.63. Zero setting the rotating base.

base can be transferred to the tilting bracket for subsequent engraving. As a further check apply the dial test indicator to the top of the bar and repeat the to-and-fro test. This is a test of your workmanship because if there is an error there is, unfortunately, nothing you can do about it except re-machine the rotating base. If you tilt the tilting base to correct it the axis of the rotating base will no longer be vertical. If the error is not large, say one thou per inch, the best thing to do is to split the difference and reposition the mark on the tilting bracket finger accordingly.

The final test is to set the axis of the wheel spindle truly parallel to the base of the machine and, therefore, the face of any wheel mounted on it truly at right angles. For this test a truly running parallel mandrel about 5 in. long must be prepared with a collet shank which fits the bore of the spindle. This too will be a test of your accuracy in boring the spindle itself but if there is a slight wobble at the far end of the mandrel not to worry. Simply take the mean of the highest and lowest readings of the dial test indicator as the spindle is slowly rotated as the true height of the centre line of the mandrel. The dial test indicator is again mounted on the workhead base as in Fig. 64 and traversed to-and-fro along the front bar but before applying the indicator to the top of the mandrel, which is the test that matters, first set the mandrel parallel to the front bar by rotating the wheelhead assembly about the vertical column. In machining the pivot screws the writer suggested, on a previous page, that not too much care need be taken in ensuring that the conical points should be truly concentric with the threads. You will now find that, with the wheelhead collar roughly centred between the arms of the wheelhead bracket, it is possible, by slacking off one pivot screw say ¼ of a turn and tightening the other a corresponding amount, to throw the axis of the spindle slightly up and down and thus to find a position where it is truly parallel to the base of the machine. If the range of adjustment is not sufficient remove one of the pivot screws, chuck it with a piece of foil under one of of the jaws in the 3-jaw chuck and

CHAPTER 9

Final Assembly

In the final assembly of the machine certain tests can be applied to check and improve the accuracy of alignment of the parts. The first, shown in Fig. 62 is to align the axis of the rotating base truly at right angles to the front horizontal bar and in this position to engrave upon the pointer of the tilting bracket an index mark in exact coincidence with the zero of the degree scale which has already been engraved upon the workhead base. A dial test indicator is therefore temporarily clamped to the rotating base and readings taken on each end of the front bar as it is rotated through 180 deg. This is an extremely sensitive test in which it is quite easy to detect a difference of say 0.001 in. in 8 in. Since this represents an angle of less than half a minute of arc it is far beyond the capacity to be read on an engraved scale but the position of the zero mark can be transferred to the pointer on the tilting base with a sharp scriber and subsequently engraved either by hand or machine.

Without disturbing the setting found in the first turn-around test the second test is applied as in Fig. 63 by fitting the long bar in its place in the rotating base. In this instance the dial test indicator is conveniently mounted on the tooth rest, clamped in its normal position on the vertical column but with the blade removed. The angular position of the rotating base is now adjusted until the workhead can be slid from one end of the front bar to the other without any change in the reading of the dial test indicator. When this position has been found, the zero mark on the rotating

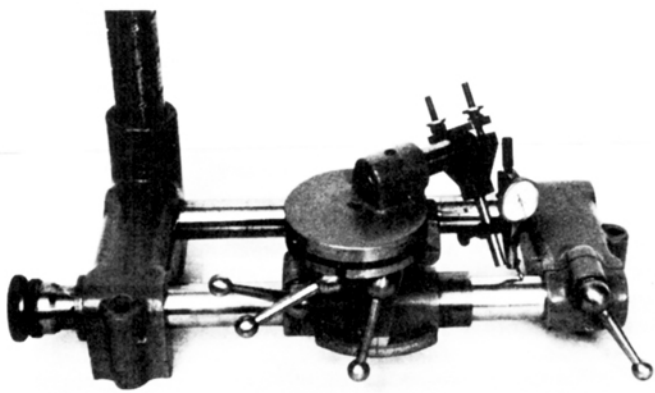


Fig. 62. Setting the tilting bracket in a "turn around" test.

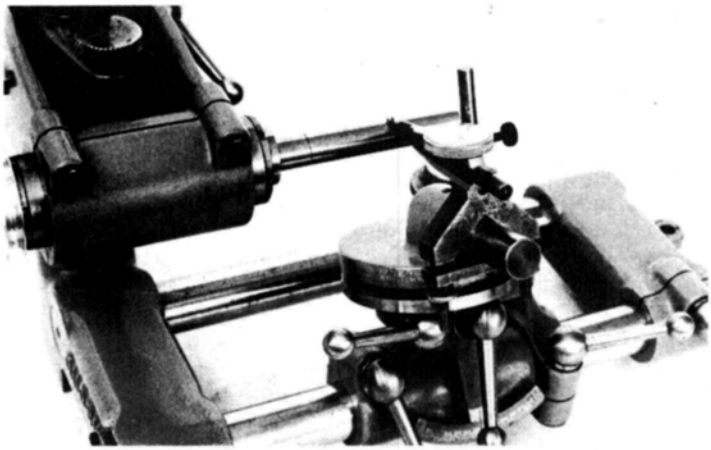


Fig. 64. Setting the axis of the spindle parallel to the bed.

return the conical point deliberately eccentric. In the final assembly the pivot screws should be drawn up quite tight, much tighter than one would normally put work between centres in the lathe but not so tight of course as to risk splitting the wheel-head bracket casting, although it is specially designed to carry this particular load.

Now is the time to transfer the zero mark on the wheelhead index ring to the collar of the wheelhead itself so that at any subsequent time it can be set parallel or at any desired angle. While all the measuring tackle is in position invert the wheelhead, set it again parallel to the front bar and transfer the zero mark on the index ring to the other end of the wheelhead collar. The head can then be used either way up with fiducial marks accurately aligned to the degree scale on the index ring.

Observant readers may have noticed that in Figs. 62 and 64 the writer is using, to support the dial test indicator, a piece of equipment which he at least has never seen in any tool makers' catalogue and which, since it has no name, he here and now christens. By analogy with a "V" block, a "Y" block. The "V" side can be clamped to anything up to 1¼ in. dia. and the bridle is slotted one side so that it can be swung clear and the "Y" block removed without having to thread it over, for example, the end of a boring bar. The knurled finger nuts are relics of the days when sparking plugs had such things! The round bar is the same size as the workshop scribing block and will therefore carry all the accessories that go with it. An alternative hole allows it to be screwed in place parallel to the axis of the "V". A most useful tool which I am sure somebody has thought of before and may even know the name.

Unless you know the trick, assembling the workhead with all those ball levers is rather like a Chinese puzzle and may, at first sight, appear impossible. The correct sequence is first to assemble the locking lever for the base and position it roughly in the locking position. The locking lever for the rotating base is then assembled to the tilting bracket, but the rotating base is NOT put in place. The tilting bracket is now assembled to the

workhead base, the absence of the rotating base allowing its locking lever to make complete revolutions and so be screwed home. Finally the rotating base is put in place and by swinging the tilting bracket to its extreme angular position there is just enough room to fit the thrust washer and its cap screw underneath.

The writer liberally anointed all protected parts with moly-disulphide grease to reduce wear and friction and to keep the grit out, but unprotected parts such as the slide bars should on no account be lubricated. If they are, the oil will pick up grit and turn into a very effective grinding paste. So all exposed parts must be kept bone dry in which case most of the grit will fall off. The rest can be wiped off with a dry kitchen tissue which is then thrown away. The preloaded angular contact bearings in the spindle can be lubricated with light spindle oil, not flooded but just sufficient so that the lower balls just dip. They can also be lubricated with molybdenum disulphide grease. Again the entire housing must not be packed with grease, it will only cause drag and unnecessary heat. Pack the, races just level with grease and assemble them thus. The writer's spindle was lubricated this way some ten years ago at the time of writing and has needed no attention ever since.

Drawings and materials for the Mk. I and Mk. II Quorn are available from Model Engineering Services, 6 Kennet Vale, Brockwell, Chesterfield, Derbyshire S40 4EW, England.

PART 2 - USING THE "QUORN" TOOL AND CUTTER GRINDER

CHAPTER 10

Choice and Dressing of Wheels

This section of the book will deal with the actual use of the machine because unless one has worked in a tool-room or seen the various operations carried out, it is a sphere of work which may be unfamiliar to most amateurs. It is, however, a fascinating operation and apart from the initial setting up which must be done with care, not a difficult one.

Before any work can be undertaken at all, the machine must be first equipped with suitable wheels and they must be dressed to be clean and sharp and to run true. Although much could and has been written about various grits and grades and the merits of different wheels for different classes of work, it is the writer's considered opinion that for amateur use the type of wheel is very much less important than the quality of the spindle bearings and the dressing of the wheel. Of course, for commercial production where consistency of finish wheel wear and speed of production are all important this is not the case and production engineers are rightly concerned to choose the best possible wheel for every job. But assuming that new wheels are to be provided the following choice is probably as good as any.

A 4 in. dia. cup wheel, of medium hardness grade and 60 to 80 grit size is a basic necessity. It is always used on the face, never the periphery, and is the standard wheel for grinding all flat surfaces on, for example, lathe and shaper tools and many other purposes besides. A typical specification, from the "Universal" range would be WA 80 JV.

In many cutter grinding operations a really sharp corner to the wheel is required to nick out the end teeth of small end mills and the like. Although the cup wheel can be dressed to a sharp corner, a lot of material may have to be removed which shortens its life and makes a mess! For "nicking out", a dish or saucer wheel is ideal since it is virtually all corner, being very narrow on the periphery and the face. It should be kept clean and sharp and only used to remove a minimum of material in circumstances where none of the other wheels will do it. 3 in. dia. is a convenient size, of the same grit size as the cup wheel, but slightly harder because it will always be cutting on a narrower surface. A typical specification, again from "Universal" would be WA 80 KV.

In many grinding operations, particularly with small or fine tooth cutters, a major problem is frequently to get the wheel into such a position that only the tooth to be operated on is ground and

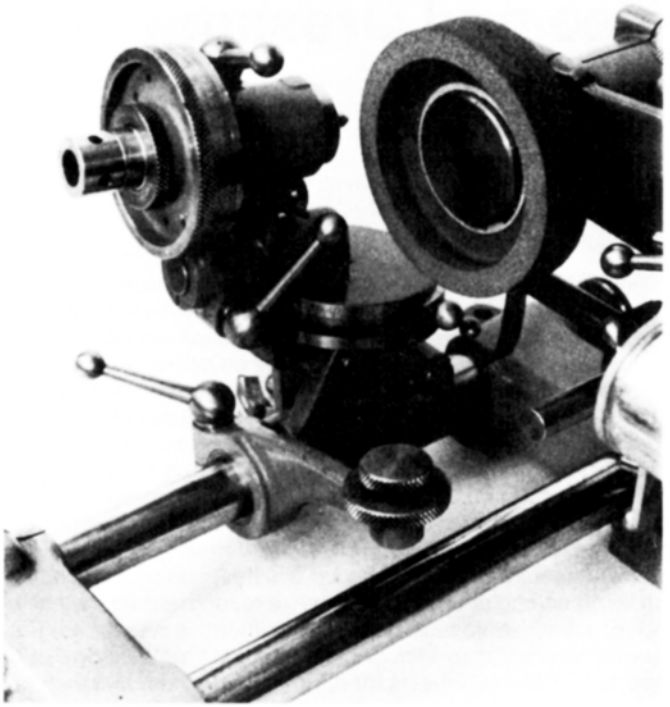


FIG 65 WHEEL DRESSING - CUP OR FACE WHEEL

WHEEL HEAD	*Axis parallel to base. Check by contacting back and front of wheel with diamond at approx. centre height. Rotation downwards at front.*
TOOTH REST	*Not used.*
FRONT BAR	*Free. Cut, not more than 1/4 thou. per pass, given by micrometer.*
WORK HEAD BASE	*Clamped to front bar.*
ROCKING LEVER	*Retracted to allow free oscillation of work head.*
TILTING BRACKET	*Set at 15° anti-clockwise.* *N.B. Diamond must always trail, never face, wheel rotation.*
ROTATING BASE	*Set zero.*
TOOL HOLDER	*Any convenient holder to suit diamond.*
METHOD OF OPERATION	*Oscillate work head with diamond slowly across face of wheel. Apply cut by front bar micrometer. Protect machine with old newspaper or kitchen tissue and wipe down thoroughly afterwards.*

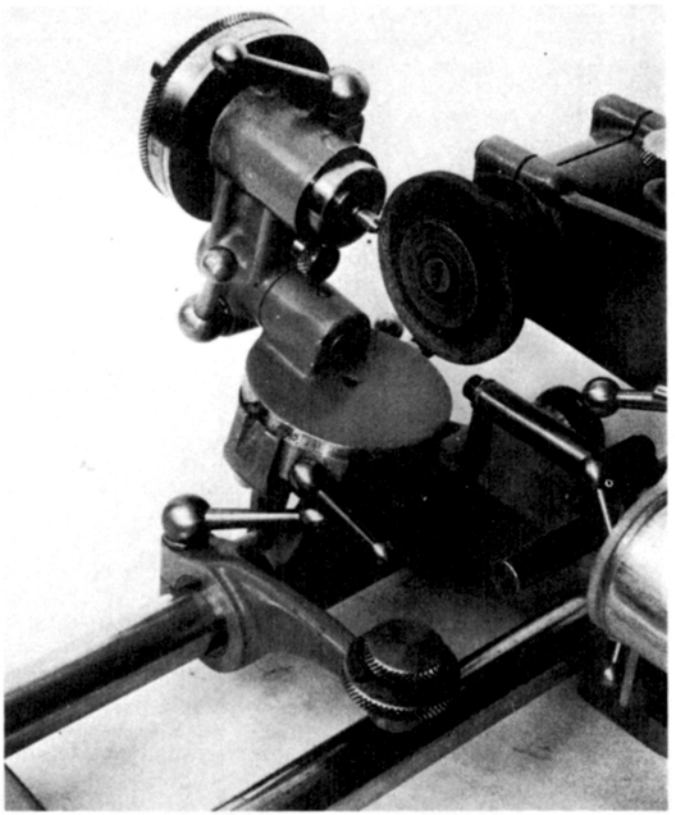


FIG 66 WHEEL DRESSING - DISC OR PLAIN WHEEL

WHEEL HEAD	*Axis parallel to base. Set height so that diamond trails wheel by approx. 15° rotation downwards at front.*
TOOTH REST	*Not used.*
FRONT BAR	*Locked. Micrometer not used.*
WORK HEAD BASE	*Free to slide on front bar.*
ROCKING LEVER	*Set to bring diamond up to wheel. Cut, not more than 1/4 thou. per pass. applied by backing off micrometer stop screw.*
TILTING BRACKET	*Set zero.*
ROTATING BASE	*Set zero.*
TOOL HOLDER	*Any convenient holder to suit diamond.*
METHOD OF OPERATION	*Slide work-head with diamond slowly back and forth along front bar keeping rocking lever stop screw firmly in contact with rear bar. Apply cut by backing off micrometer stop screw. Protect machine with old newspaper or kitchen tissue and wipe down thoroughly afterwards.*

not everything else in the vicinity–including the machine itself. For this sort of work a small, say 2 in. dia. taper cup wheel is extremely useful. It can be the same grit and grade as the larger cup wheel and like it is always used on the face not the periphery.

Finally a plain disc wheel about 3 in. dia. and of the same grit and grade as the dish wheel will be used on very many occasions for regular grinding including maybe plain cylindrical grinding. It need not be very wide, 1/4 in. to 3/8 in. is ample, and it is convenient to have a second wheel of the same size which can be dressed on its periphery for special purpose angle and radius grinding. Again a WA 80 KV is suitable.

Each wheel should be permanently mounted on its own arbor so that, once it has been dressed true, it can be removed from and put back into the spindle without further dressing. The arbors must have substantial true-running flanges, between which the wheel is firmly clamped, with soft paper washers between, but not so hard that there is any risk of cracking. In the case of the cup wheels it is important that no part of the arbor projects beyond the face of the wheel, even when it is dressed down to its minimum usable thickness. For these arbors the writer has found that a single 1/4 in. B.S.F. countersunk cap screw, tapped into the body, gives ample holding power for small wheels and a minimum of protrusion.

Having chosen and mounted the wheels, the next operation is to dress them and for this a diamond is essential. They can be obtained from tool suppliers at a very modest price and what you will get for your money will be a piece of mild steel 1/4 in. dia. and about 2 in. long with a wee chip of diamond in one end. Treat it with care. Although diamonds are hard they are also brittle and if you drop it on its nose on the floor you may chip the diamond or knock it out of its setting altogether. Once lost you may not have much chance of finding it again and the steel shank is not much use without it!

The dressing of a cup wheel is shown in Fig. 65. The diamond is held in any convenient holder, here the collet spindle with a 1/4 in. collet is being used, and presented to the wheel with a trailing or drag angle, never a leading angle, of about 15 deg. This is easily accomplished by rotating the tilting head this amount from the vertical position. The wheel is run at its normal speed, but check that its direction of rotation is such that the diamond trails and does not lead otherwise it may be knocked out of its setting. Lock all settings except that which allows the front bar to move and under control of the front bar micrometer screw cautiously bring the diamond into contact with the face of the wheel. Only very light cuts should be taken, about 1/4 of a thou. at a time, by rocking the entire work head and with it the diamond slowly across the face of the wheel. Do not be afraid that light cuts and a slow feed will wear the diamond, it won't as it is much harder than the material of the wheel and much more likely to be damaged by overheating due to excessive feed and pressure. Little and often should be the rule as it is far better to restore the face, as soon as it is beginning to show signs of wear, with a single light pass, than to leave it until heavy redressing is necessary.

But it must be admitted that whether it be done frequently or seldom, wheel dressing is a messy operation, one is producing not grinding dust which is bad enough but fine abrasive power of highest quality!

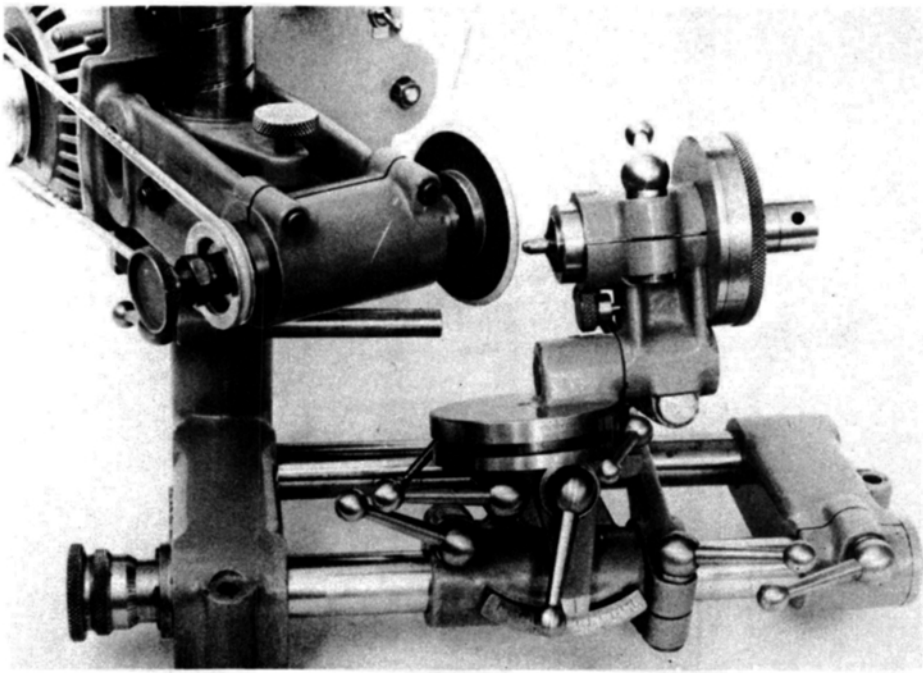


FIG 67 WHEEL DRESSING - ANGLE WHEEL

WHEEL HEAD	*Set at required angle with bevel gauge or protractor. Diamond at exact centre height of wheel. Rotation downwards at front.*
TOOTH REST	*Not used.*
FRONT BAR	*Free. Cut, not more than 1/4 thou. per pass, given by micrometer.*
WORK HEAD BASE	*Clamped to front bar.*
ROCKING LEVER	*Retracted to allow free oscillation of work head.*
TILTING BRACKET	*Set 15° anti-clockwise.* *N.B. Diamond must always trail, never face, wheel rotation.*
ROTATING BASE	*Set zero.*
TOOL HOLDER	*Any convenient holder to suit diamond.*
METHOD OF OPERATION	*Oscillate work head with diamond slowly across face of wheel applying cut by backing off front bar micrometer screw. L.H. side of wheel is most conveniently dressed by the method given in Fig 66, setting the wheel head to an appropriate angle. Protect machine with old newspaper or kitchen tissue and wipe down thoroughly afterwards.*

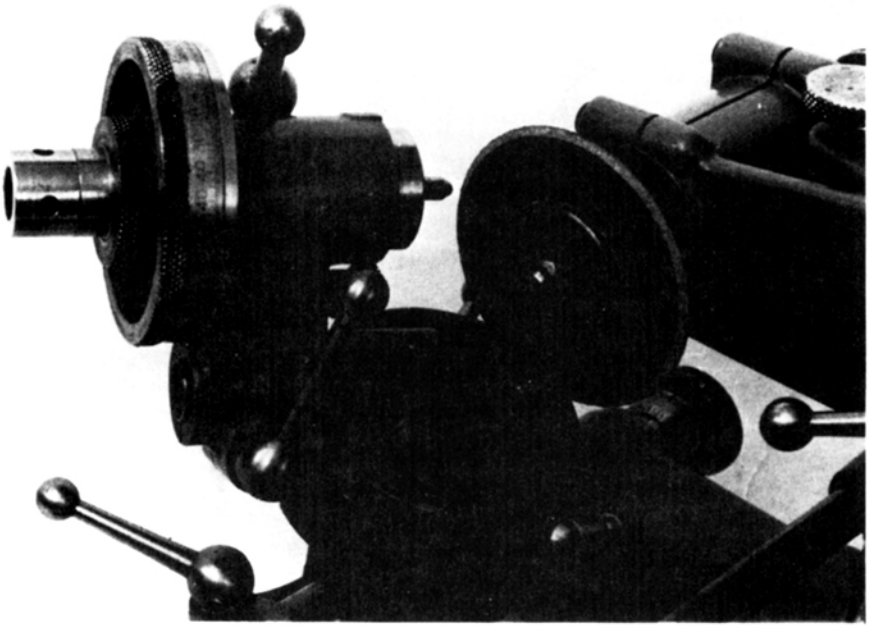


FIG 68 WHEEL DRESSING - RADIUS DRESSING

WHEEL HEAD	*Axis parallel to base. Diamond to exact centre height of wheel. Rotation downwards at front.*
TOOTH REST	*Not used.*
FRONT BAR	*Use micrometer screw to bring diamond into exact coincidence with R.H. side or face of wheel to be dressed and then set thimble to zero. Back off before taking cut.*
WORK HEAD BASE	*Clamped to front bar.*
ROCKING LEVER	*Use micrometer stop screw to bring diamond into exact coincidence with L.H. face or periphery of wheel and lock.*
TILTING BRACKET	*Set zero.*
ROTATING BASE	*Free. Set stops to limit travel in either direction.*
TOOL HOLDER	*Any convenient holder to suit diamond. Tip of diamond must be aligned with axis of rotating base by means of a setting pin and distant from it by a distance equal to the radius to be ground. (See also Fig 80.)*
METHOD OF OPERATION	*Oscillate rotating base between stops and gradually bring work head back to zero position as indicated by front bar micrometer thimble.*

As the machine is portable it can readily be taken outside for the wheel dressing job. If not all other machines in the workshop should be carefully covered up before dressing takes place. In either case protect the machine itself with old newspapers or kitchen tissue and give it a good wipe down afterwards.

Dressing the periphery of a plain disc wheel is shown in Fig. 66. As before, the diamond is not exactly at right angles to the edge of the wheel but slightly off-set, about 15 deg. by raising the wheelhead. All settings are locked after preliminary adjustment except that the workhead is left to slide free along the front bar. The cut is put on by backing off the micrometer stop screw on the rocking lever and taken by sliding the work-head and the diamond bodily past the wheel. Again light cuts, not more than ¼ of a thou. at a time.

Angle dressing is shown in Fig. 67. The diamond and the workhead are used in exactly the same way as in dressing a cup wheel but the wheelhead is rotated on the vertical column to give the required angle, here 27½ deg., to produce a wheel for grinding screw threads. As there is no protractor scale associated with the wheelhead and the vertical column, the angle must be set by means of a bevel protractor or angle gauge. When one side of the wheel is dressed, the other side is done by re-setting the wheelhead to an appropriate position. If double angle wheels such as the one in the photograph are to be dressed to a really sharp corner the final cuts must be very light indeed, otherwise the edge of the wheel will be broken down by the pressure of the diamond, particularly if it has not been itself kept sharp, by turning it round from time to time to present a new facet to the wheel.

Another method of angle dressing is shown in Fig. 68. Here the wheel-head is left in its normal fore-and-aft position, but the rotating base is turned to the required dressing angle, using its own protractor scale for the purpose, and locked. The cut is put on, as in the case of dressing a cup wheel, by moving the entire work-head forward under control of the micrometer screw, but it is taken by rocking the tool-holder back and forth on its spigot, the locking clamp of course being left free. This method is quick and easy to use, but it is only suitable for relatively narrow angular faces because the diamond is moving in the arc of a circle, not a true straight line, and cannot therefore generate a truly conical surface. But over a small distance the difference is minute and may safely be ignored.

An almost exactly similar setting is used for radius dressing, except that in this case it is the rotating base which is left free and, rocked between stops, swings the diamond in the arc of a circle to dress a corresponding radius on the periphery of the wheel. Radius dressing however needs a special preliminary setting of the machine and this will be dealt with more fully when radius grinding is dealt with.

Dish and saucer wheels need a double dressing to produce a sharp corner, first on the face of the wheel as in Fig. 65 and then on the periphery as in Fig. 67. In order to get a corner which will hold up a little longer it is permissible to overdress the wheel slightly on each face, say 1 deg., then as it wears it will come closer to a true right angle rather than immediately wearing into an obtuse angle. Again as in dressing an angle wheel the final cuts with the diamond must be very light if a really sharp corner is to be obtained.

CHAPTER 11

Grinding Lathe and Sharper Tools

Since grinding the flat surfaces of lathe and shaper tools is, in general, simpler than cutter grinding it will be dealt with first and it is suggested that to gain experience with the machine a few such tools should be ground, even if strictly not needed, before embarking on more easily spoilt and expensive cutters.

The first operation is to align the square hole in the tool holder with the rest of the machine. So with the long setting pin in the hole in the rotating base and a tool in the holder slacken off both the spindle and bracket clamping bolts and bring the base of the tool firmly in contact with the flat on the setting pin as in Fig. 69. Lock both clamps, free the index ring and set it to any one of its four zeroes and relock. Free the spindle lock, remove the setting pin and you are ready to grind any conceivable angle without further setting, each face of the tool being represented of course by one of the four quadrants into which the degree scale has been divided.

Do not worry that the centre of the square hole is off-centre. In tool grinding we are concerned with angles and the wall of the square hole is part of a plane surface which extends to infinity in all directions and upon which it does not matter where we put the tool.

Grinding a tool in the Quorn is ridiculously easy and the parting tool shown in Fig. 70 has been specially chosen to illustrate the type of work of which the machine is capable. Normally parting tools only need 1 deg. side clearance and 1 deg. side rake to cut cleanly, but these angles are impossible to judge by eye. Consequently to make sure there *is* clearance the angles are exaggerated and, in the writer's case at least, finish up with a feather edge at the rear and base of the tool which makes it unnecessarily weak. With the machine it is only necessary to turn the tool holder 1 deg. back from the zero position to establish the side clearance and to turn the rotating base 1 deg. from its zero position to establish the side rake and the tool will come out spot on and right first time. To grind the other side of the tool there is no need to reset it.

Simply turn the tool holder through 180 deg. plus 1 deg. more to establish the side clearance and continue grinding. There is no need to reset the rotating base, it will automatically give the same side rake to both sides of the tool.

The Quorn is an absolute wizard for producing parting tools and the like to an exact width for operations such as cutting square threads, making grooves for piston and "O" rings and so on where the width of the groove is important. With the tool under control of the front bar and its micrometer screw, not only are the angles held during successive passes, but one can really take off a whisker and size the tool to tenth thou limits. The work head can of course be

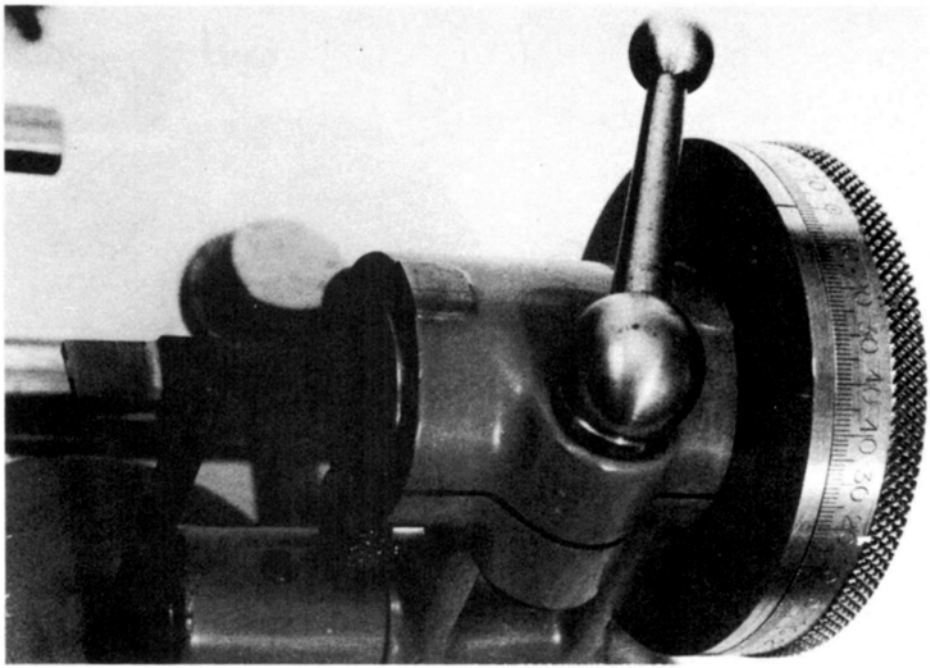


FIG 69 TOOL GRINDING - ZERO SETTING

1. *Clamp tool in tool holder. Set screws must be below surface of holder.*
2. *Insert long setting pin in rotating base.*
3. *Insert tool holder in tool holder bracket.*
4. *Free bracket and spindle locks. Press base of tool firmly against face of setting pin and retighten both locks.*
5. *Free the index ring, set to zero and relock.*
6. *Remove the tool holder and the setting pin. Replace the tool holder in any desired quadrant, setting it by means of the degree scale on the index plate and locking it when set.*

swung quite clear of the machine while these measurements are being taken, but it is a wise precaution to stop the wheel rotating first!

Front clearance is very simply dealt with for all tools by setting the required angle on the tilting bracket, as in Fig. 71. Front rake angles, positive or negative, are dealt with by setting the rotating base but the tool holder degree scale is

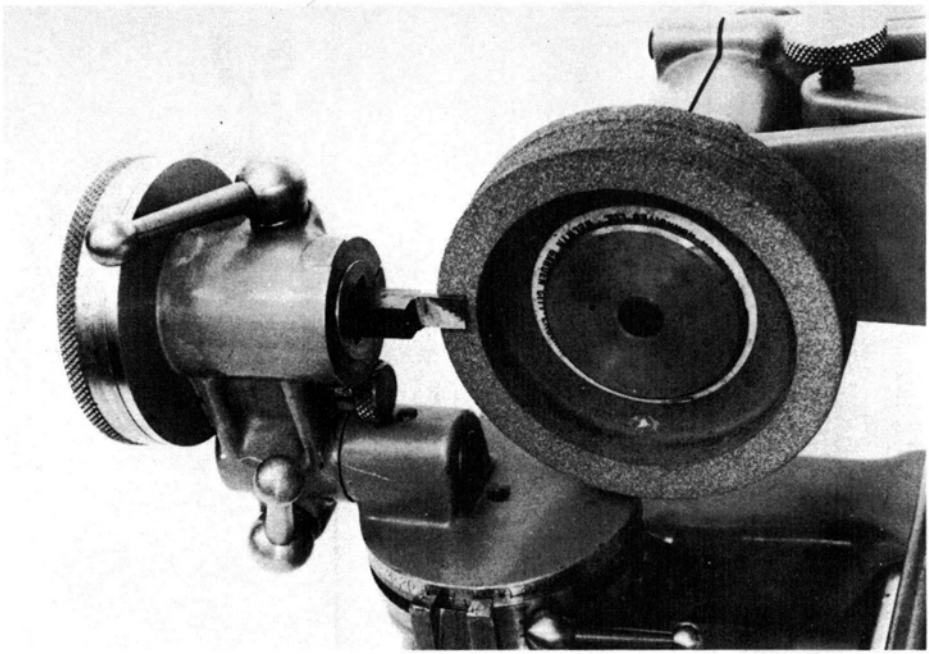


FIG 70 TOOL GRINDING - SIDE RAKE AND CLEARANCE

WHEEL HEAD	*Axis parallel to base. Rotation towards cutting edge.*
TOOTH REST	*Not used.*
FRONT BAR	*Free. Cut applied by micrometer.*
WORK HEAD BASE	*Clamped to front bar.*
ROCKING LEVER	*Set to limit travel of work towards wheel if shoulder present on tool.*
TILTING BRACKET	*Set zero.*
ROTATING BASE	*Set to give side rake. 1° back for parting tools, 0° for facing tools, half thread angle for screw cutting tools.*
TOOL HOLDER	*Set to clearance angle. 1° for parting tools, 5-7° for turning and facing tools. Reverse side of tool ground the same way by turning tool holder through 180° and measuring angles in second quadrant. Top and back rake ground by turning tool holder through 90° and measuring angles in first quadrant.*
METHOD OF OPERATION	*Oscillate tool across face of wheel applying cut by backing off micrometer. All faces of the tool can be ground at a single setting.*

normally set to zero, unless that is one wishes to go into "compound geometry". By turning the tool into the next quadrant top rake angles, front and back, can all be dealt with at the same setting. If required the entire tool holder with the index ring and the tool in place may be removed for examination and put back again afterwards without loss of registration or accuracy.

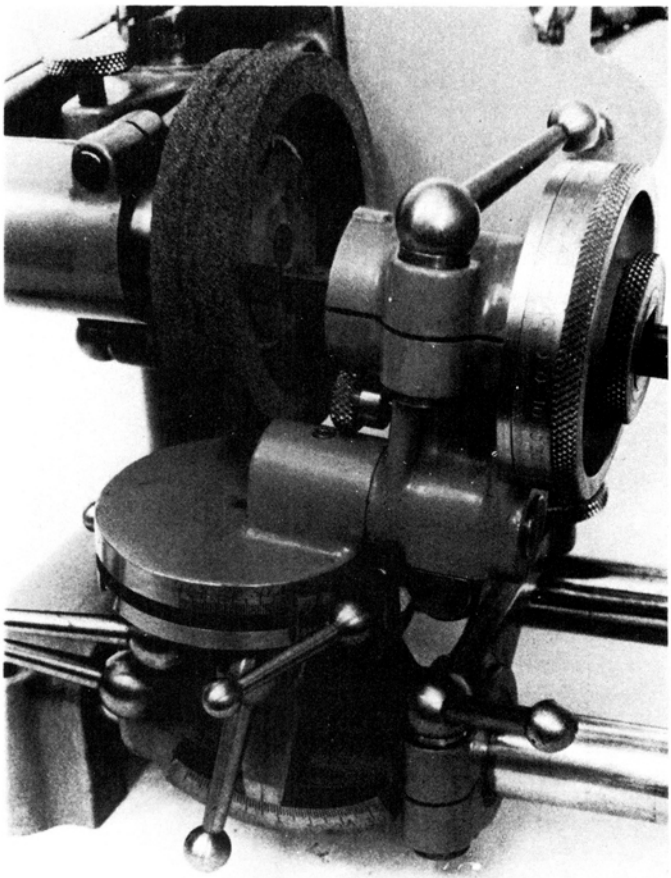


FIG 71 TOOL GRINDING - FRONT RAKE AND CLEARANCE

WHEEL HEAD	*Axis parallel to base. Rotation towards cutting edge.*
TOOTH REST	*Not used.*
FRONT BAR	*Free. Cut applied by micrometer.*
WORK HEAD BASE	*Clamped to front bar.*
ROCKING LEVER	*Retracted to allow free movement of work head.*
TILTING BRACKET	*Set to front clearance angle, usually 5-7°*
ROTATING BASE	*Set to front clearance angle. 0° for parting tools, 5-7° for facing tools.*
TOOL HOLDER	*Set zero.*
METHOD OF OPERATION	*Oscillate tool across face of wheel applying cut by backing off micrometer screw. These operations can conveniently follow or precede those described in Fig. 70 without disturbing the tool in its holder or re-setting it.*

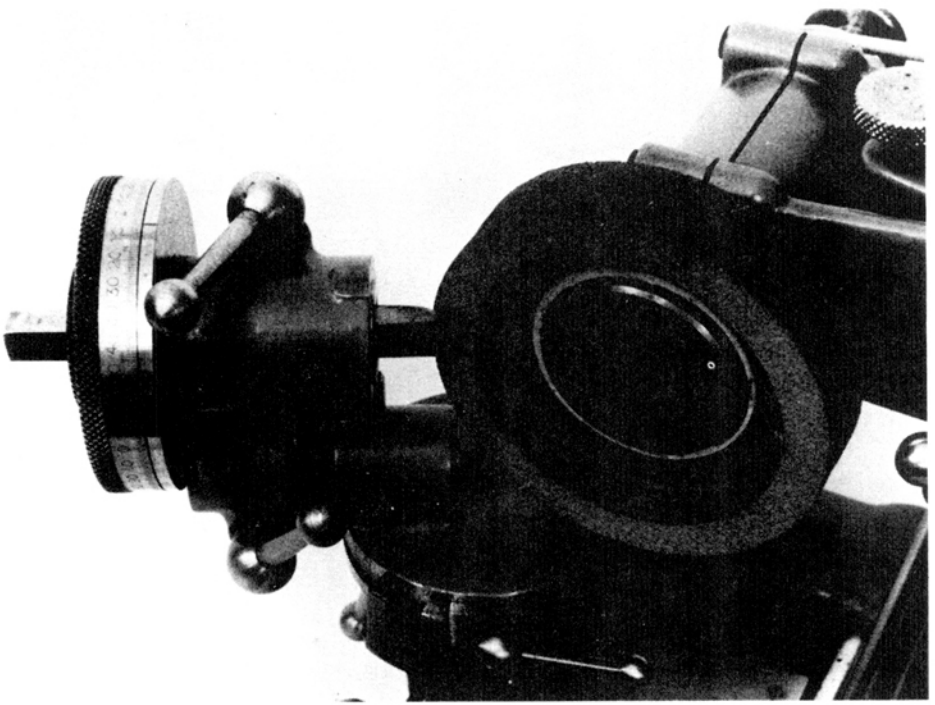


FIG 72 TOOL GRINDING - SCREW CUTTING OR FORM TOOL

WHEEL HEAD	*Axis parallel to base. Rotation against cutting edge.*
TOOTH REST	*Not used.*
FRONT BAR	*Free. Cut applied by micrometer.*
WORK HEAD BASE	*Clamped to front bar.*
ROCKING LEVER	*Retracted.*
TILTING BRACKET	*Set zero.*
ROTATING BASE	*Set to give rake angle required, e.g. half thread angle for screw cutting tool. If both sides ground at same setting point will be symmetrical with axis of tool.*
TOOL HOLDER	*Set to clearance angle. Positive (clockwise) when grinding L.H.S., and negative (anti-clockwise) when grinding R.H.S. of tool.*
METHOD OF OPERATION	*Oscillate tool across face of wheel applying cut by backing off micrometer screw.*

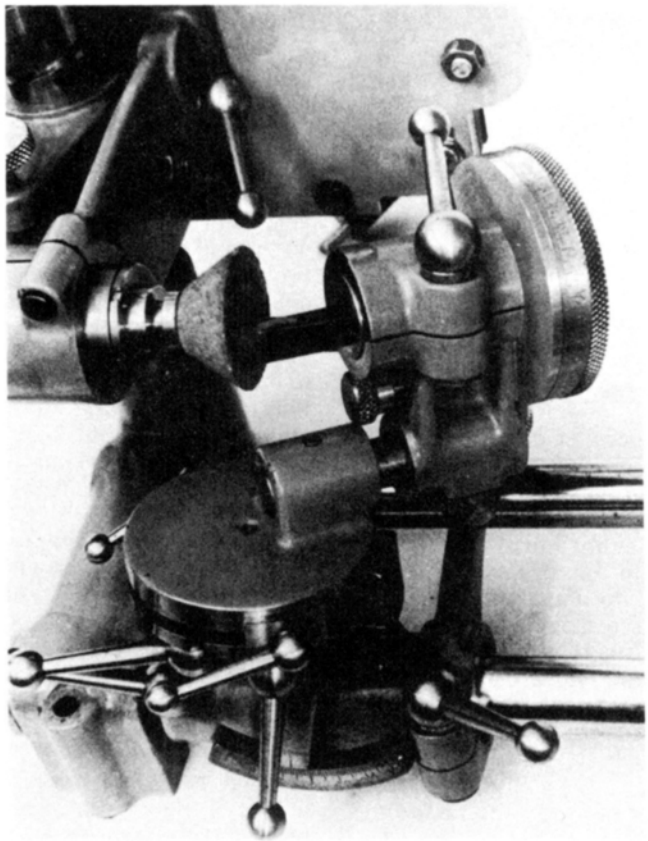


FIG 73 TOOL GRINDING - RADIUSING

WHEEL HEAD	*Axis parallel to base. Rotation downwards at front.*
TOOTH REST	*Not used.*
FRONT BAR	*Free. Cut applied by micrometer.*
WORK HEAD BASE	*Clamped to front bar.*
ROCKING LEVER	*Set to centralise work on face of wheel.*
TILTING BRACKET	*Set to front clearance angle.*
ROTATING BASE	*Free. Set stops to required angles.*
TOOL HOLDER	*Set zero. For compound angles set to difference between front and side clearance angles. e.g. 5° front clearance, 7° side clearance, set tool holder to 7 – 5 = 2° positive (clockwise). If the work is to make more than 90° rotation it may be necessary to retract the tool holder bracket on its spigot and extend the tool accordingly and to use a small wheel to gain necessary clearance.*
METHOD OF OPERATION	*The tangent faces of the tool, which should have been ground previously, must be aligned at the required radius with the axis of the rotating base, using either the long setting pin or, more conveniently, the setting micrometer. The work is rocked between stops and advanced towards the wheel by the front bar micrometer screw until the radius blends with the tangent faces of the tool.*

Grinding angled tools such as the 55 deg. screw cutting tool shown in Fig. 72 follows exactly similar principles. The tool angle, in this case 27½ deg., is set directly on the rotating base scale and the side clearance angle on the tool holder degree scale. The opposite side of the tool, here in fact shown being ground upside down, is dealt with by first turning it into the opposite quadrant and then setting the required clearance angle which need not of course be the same as the first. The tilting bracket is set to zero because in the case of a double angled tool a separate front clearance is not required.

As in the case of cutters, radiusing tools is a trickier operation, mainly in the setting up, but the Quorn will do it and do it very well. The long setting pin is once again brought into play to align the tool faces with the axis of the rotating base but to do this the tool holder bracket must, in most cases, be swung to one side. This of course nullifies the previous setting for horizontality of the base of the tool so the tool holder must be reset a corresponding amount and the degree scale brought to zero again. The tool is then advanced in its holder by the amount of the radius to be formed. The operation of radiusing the tip of screw cutting tool is shown in Fig. 73 in which it will be seen that to provide clearance as the tool is swung from one side of the machine to the other a small cup wheel is being used and the tool holder bracket has been drawn back somewhat from its normal working position. The tilting bracket is set to an angle, here 7½ deg., which gives a clearance angle to both the sides and the front of the tool at a single setting as it is swung from one side to the other, the tool holder scale being in this instance kept at zero. If both the tilting bracket *and* the tool holder scale are used at the same time it is possible to grind radiused tools with compound geometry, for example 7 deg. side clearance and 5 deg. front clearance both connected together by a continuous unbroken radius. This can be done of course by setting the tilting bracket to the required front clearance angle, in the example given 5 deg. and the tool holder to the *difference* in the clearance angles, that is 7 – 5 = 2 deg. more to give the side clearance angle. This may be a bit exotic for most work but is included to indicate the full capabilites of the machine.

But many other simpler form tools require radiusing to form the profiles on locomotive chimneys, poppet valve stems and the like and in future. Exhibitions the Judges will no doubt be looking for accurate radii perfectly blended into the rest of the profile! Internal or female radii can also be ground by setting the work *behind* the axis of the rotating base and bringing the wheel across to meet it. Because of clearance problems the arc can never be greater than 180 deg., in practice nearer 90 deg. and for very small radii it is probably best to first dress the required radius on the wheel and then to use it to form grind the tool. In this case it is the diamond which is set up with the long setting pin, exactly as if it were itself a cutting tool, but of course to a negative radius if it is to be required to produce a positive radius on the wheel.

CHAPTER 12

Setting Clearance Angles

So, having mounted the wheels and dressed them true, the serious business of cutter grinding can begin in earnest. The basic principle of nearly all cutter grinding, which may be likened to the "first position" in ballet, is shown in Fig. 74. The cutter to be ground is mounted on a mandrel or arbor held in the workhead with the tooth to be ground in contact with the tooth rest. The entire workhead and the cutter is then advanced towards the grinding wheel under control of the rocking lever micrometer adjusting screw until cutting begins. All adjustments are then locked and the cutter ground by sliding it back and forth with the tooth firmly in contact with the tooth rest. When one tooth is finished the cutter is slid right back out of contact with the tooth rest and turned until the next tooth can be brought into position. It is then ground in exactly the same way and so on round the cutter until all the teeth have been dealt with. After the first round the cutter should be inspected to see if all the teeth have cleaned up. If they have not another round with a slightly increased feed, given by the micrometer adjustment screw, is called for. Here it is to be emphasised that the aim in cutter grinding is to take as little off as possible in order to restore sharpness. Whereas 0.005 in. may be a light cut in a lathe it is a whopping cut in a tool grinder where 0.0005 in. may be sufficient to resharpen a cutter which has not been left to get in a really bad condition.

The actual process of grinding, which even in much larger commercial machines is always carried out manually, is in fact extremely simple because, once the adjustments have been made and locked, each tooth will be exactly the same height and angle as its fellows and follow exactly the correct spiral angle, be it right or left handed, steep or slow or even straight. But the efficiency of a cutter depends not only on having all the teeth ground to an equal height, but also on having each one ground to the correct clearance angle.

This is so important that something must be said of the way in which the tooth rest is used to control the clearance angle. In Fig. 75 the diagram to the left shows a cutter being ground on the periphery of a plain disc wheel, the "first position" which has already been described. Now if the centre of the cutter, the tip of the tooth rest and the centre of the grinding wheel were all in the same straight line, although the tooth might be ground sharp, it would have no clearance angle and so could not cut properly, if at all. To give the cutting edge clearance the centre of the grinding wheel must be *raised* by an amount shown in the diagram as the distance "A" This distance is quite critical to good cutter grinding and depends on

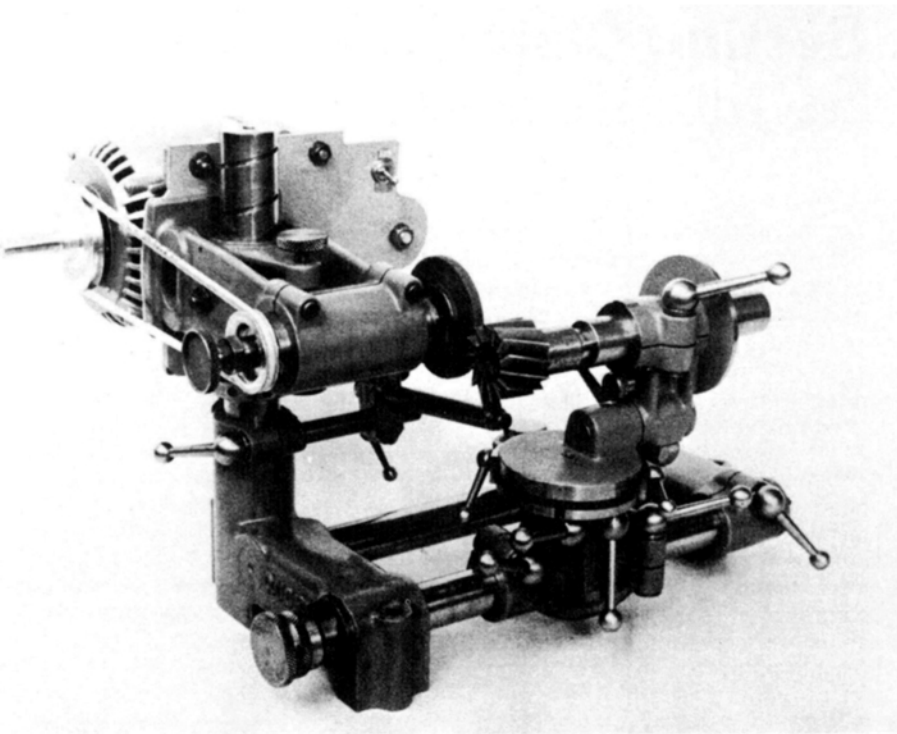


FIG 74 CUTTER GRINDING - SHELL, SLAB AND END MILLS (DISC WHEEL)

WHEEL HEAD	*Axis parallel to base. Height set according to page 89. Rotation downwards at front. N.B. This is important to hold work against tooth rest.*
TOOTH REST	*Height set according to page 89, may be angled to suit R.H. or L.H. cutter.*
FRONT BAR	*Free when setting. Locked when grinding.*
WORK HEAD BASE	*Clamped to front bar.*
ROCKING LEVER	*Set to bring work into contact with wheel. Cut applied by backing off micrometer stop screw.*
TILTING BRACKET	*Set zero.*
ROTATING BASE	*Set zero.*
TOOL HOLDER	*Mandrel to suit cutter to be ground. Cutter may slide and rotate on a dead mandrel clamped in tool holder or be fastened to live mandrel sliding free in tool holder. Tool holder may be set away from or towards wheel to accommodate work/wheels of different diameters.*
METHOD OF OPERATION	*After locking all settings slide cutter back and forth firmly in contact with tooth rest. Grind every tooth in turn at same setting. Free front bar and back off rocking lever stop screw to increase cut.*

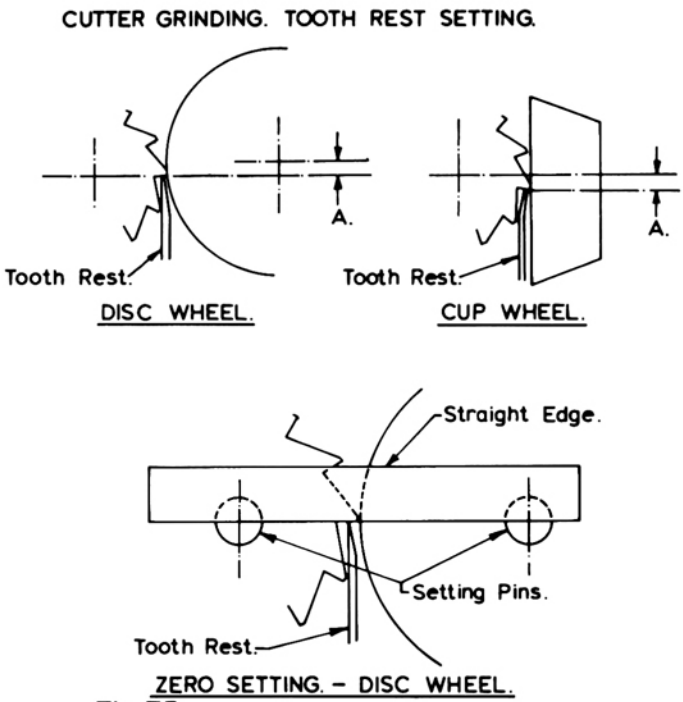


Fig.75.

the clearance angle to be given and the diameter of the *wheel*. It is not affected by the diameter of the *cutter*.

Although with experience it can be roughly established by eye, the Quorn can be set with considerable precision with the aid of two simple setting pins and a straight edge. So first having mounted the cutter on a suitable arbor and selected the grinding wheel that is going to be used, set up the machine as in Fig. 74 and bring the tooth rest into its working position by eye. Now temporarily remove the wheel and the cutter and replace them by the setting pins shown in Fig. 75. These can be very accurately made by the Quorn itself. Rough out the flat to something over half diameter, harden the pins and leave them glass hard and then grind them down to exactly half diameter using the face of a cup or dish wheel. You will not find it difficult to work to a couple of tenths of a thou. The diameter of the shanks of the shorter setting pins, of which two will be required, is not important. The writer finds ¼ in. convenient because he has collets this size which fit both the wheel spindle and the workhead arbors. Alternatively the pins may be made with shanks to suit the machine without the use of collets, say according to Fig. 49 for the wheel spindle and with taper shanks to suit various cutter arbors. Plain arbors may merely have a flat on one end, the only thing that is important is that the

flat is exactly on the centre line.

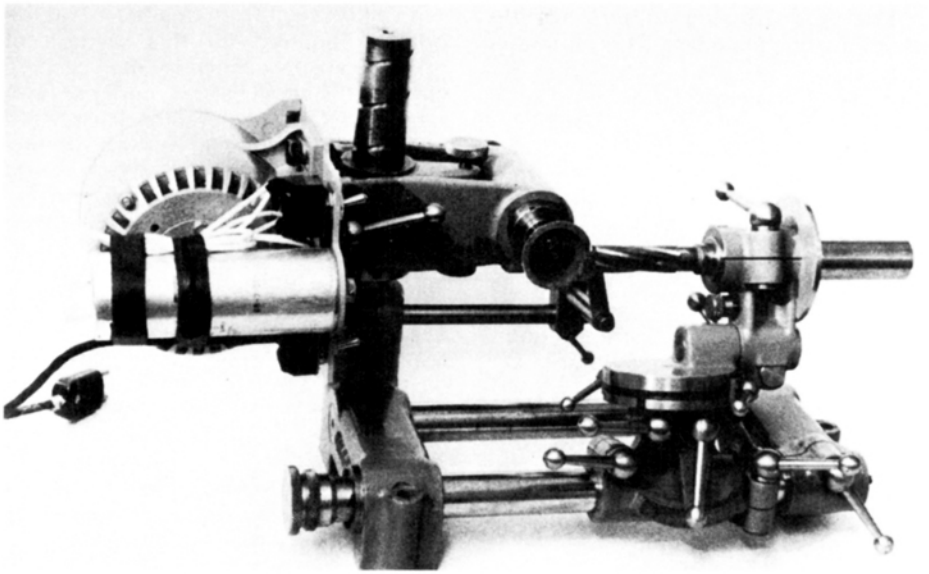
With both setting pins in position it is now very easy, as in Fig. 75, to adjust the height of the tooth rest until it is exactly on the centre line. This of course establishes the zero position in which the cutter, if it were ground, would have no clearance. To give it clearance the wheel spindle must be *raised* and the amount will depend on the class of work to be done. 5 deg. clearance is usually recommended for light work and finishing as the cutting edge is stronger and wears less. 7 deg. gives freer cutting and is more suitable for use with softer materials where deeper cuts can be taken. Probably 6 deg. is the best all-round compromise. The following table gives therefore the amount "A" by which the wheel spindle must be raised to give various clearance angles with different sizes of wheel. It has been rounded off to the nearest 0.005 in. because even with small wheels and cutters there is not much point in attempting to work much closer than this–some tables only give the nearest 1/64 in.

Distance to Set the Centre of the Wheel ABOVE the Cutter Centre (Disc Wheel) to nearest 0.005 in.

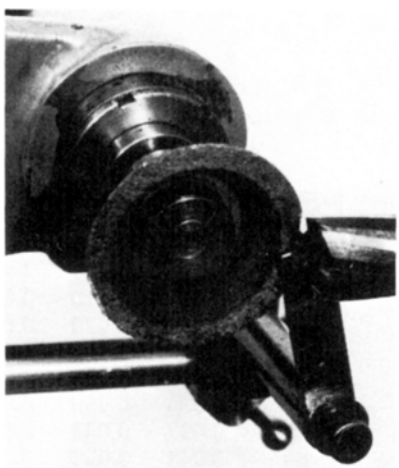
Wheel Diameter	Clearance Angle		
ins	5 deg	6 deg	7 deg
2	0.090	0.105	0.120
2 1/4	0.100	0.120	0.135
2 1/2	0.110	0.130	0.150
2 3/4	0.120	0.145	0.165
3	0.130	0.155	0.180
3 1/4	0.145	0.170	0.195
3 1/2	0.155	0.185	0.210
3 3/4	0.165	0.195	0.225
4	0.175	0.210	0.240

These distances may be readily set by a dial test indicator bearing on the flat face of the setting pin, and this is one of those instances where a dial test indicator may be used to set a distance rather than to record a difference, or the fine adjustment built into the machine itself may be used. Bearing in mind that the fine adjustment screws have a pitch of 32 t.p.i. and are operating on a 1 5/8 in. to 2 7/8 in. lever arm in relation to the centre line of the spindle, one turn of the adjusting screw will raise, or lower, the wheel head 0.055 in. near enough. If therefore the heads of the screws are engraved with eleven equal divisions, a matter which might have been attended to when they were made but which can nevertheless be attended to now, a movement of one division will raise the wheel head 0.005 in. Suppose for instance one was working with a 3 in. wheel and wanted 6 deg. clearance angle. The table shows that the wheel must be raised 0.155 in. Fives into one hundred and fifty-five goes 31 times, so turn the adjusting screw three whole turns less two divisions, that is 31 divisions. For 5 deg. clearance 5 divisions less, for 7 deg. clearance 5 divisions more.

This may sound a long and complicated rigmarole and so to some extent it is, but unless the initial setting is accurately carried out the cutters cannot possibly be ground accurately. It is one reason for the popularity, in commercial work, of "throw-away" cutters and for the existence of cutter grinding services where, once a machine has been set up, a gross of cutters can be ground in little more time than it takes to set up for one. But there are many cutters around which, although it may not be commercially viable to recondition them, can nevertheless give good service to the model engineer if he is prepared to spend a little time and trouble on them.



WHEEL HEAD	*Axis at right angles to base. Height as convenient. Rotation downwards at front. N.B. This is important to hold work against tooth rest.*
TOOTH REST	*Height set according to page 89. May be angled to suit R.H. or L.H. cutter.*
FRONT BAR	*Free when setting. Locked when grinding.*
WORK HEAD BASE	*Clamped to front bar.*
ROCKING LEVER	*Set to bring work into contact with wheel. Cut applied by backing off micrometer stop screw.*
TILTING BRACKET	*Set zero.*
ROTATING BASE	*Set zero.*
TOOL HOLDER	*Mandrel to suit cutter. Cutter may slide and rotate on a dead mandrel clamped in tool holder or be fastened to live mandrel sliding free in tool holder. Tool holder may be set towards or away from wheel to accommodate work/wheels of different diameters.*
METHOD OF OPERATION	*After locking all settings slide cutter back and forth firmly in contact with tooth rest. Grind every tooth in turn at same setting. Free front bar and apply next cut by backing off rocking lever stop screw. Re-lock before grinding.*



Although grinding cutters on the periphery of a plain disc wheel is widely practised, it has the disadvantage that the cutting edge instead of being flat is left as the radius of circle equal to that of the grinding wheel which formed it. This has the disadvantage that the cutting edge is slightly weaker than it otherwise would be and the clearance angle is less precise. In high class work cutters are ground against the face of a cup wheel and this leads us to the "second position" shown in Fig. 76. Here the entire wheel-head has been inverted and turned through 90 deg. so that the face of a cup wheel is parallel to the axis of the cutter to be ground, in this case a 5/8 in. by 2 in. end mill. In grinding, the cutter is slid backwards and forwards exactly as before but the setting of the tooth rest is quite different.

Reference back to the right-hand diagram of Fig. 75 will show that because the face of the wheel is always vertical, to obtain clearance the tooth rest must be set *below* the centre line of the work. The distance "A" in this case depends on the clearance angle required and the diameter of the *cutter*. The diameter of the wheel does not come into it since the face of the wheel is flat and in the Quorn always vertical. A different table of offsets is required for "second position" grinding and this is reproduced below:-

Distance to Set Tooth Rest BELOW the Cutter Center Cup Wheel

Cutter Diameter	Clearance Angle		
ins	5 deg	6 deg	7 deg
1/4	0.011	0.013	0.015
3/8	0.015	0.020	0.022
1/2	0.022	0.026	0.030
5/8	0.028	0.033	0.037
3/4	0.033	0.039	0.045
7/8	0.037	0.046	0.052
1	0.044	0.052	0.060

It will be seen from this table that the off-sets required for this method of grinding are very much smaller, particularly for the small cutters, and therefore require setting with great precision–the difference in the height of the tooth rest for 5 deg. and 6 deg. clearance angle with a 1/4 in. dia. cutter is only 0.002 in. For this a dial test indicator working from the face of a setting pin which temporarily replaces the cutter would certainly be necessary. A quicker and easier way is to make up a setting gauge. Made from hardened gauge plate each of the three corners can be ground, on the Quorn itself, to give clearance angles of 5 deg., 6 deg., and 7 deg. respectively. Although aligning it up against the face of the grinding wheel, stationary of course, may not be the best practice, it is at least certain that the angles will be right.

In grinding helical tooth cutters either in the "first" or "second" position, consideration must be given to which part of the face will actually control the clearance angle. With a right-handed cutter the offset is continually increasing and therefore the first part of the cutter to engage the wheel will control the clearance angle. With a left-handed cutter the converse is true and the position of the tooth rest should be gauged accordingly. There is therefore no advantage in using broad faced wheels and indeed a wheel may be deliberately set slightly away from strict parallelism or dressed slightly concave to localise the point of contact.

CHAPTER 13

Grinding End, Slot, Face and Side Mills

Many of the operations in cutter grinding are basically the same regardless of the type of cutter being ground. Thus the sharpening of the end teeth of end mills are the same as those for a slot drill, a shell end mill or the side teeth of a side and face cutter and will therefore be dealt with together. Again to gain experience it is suggested that the first attempt should be to sharpen the end teeth of a not too small end mill, say ½ in. to ¾ in. diameter, which is one of the easiest and quickest operations in cutter grinding.

A close-up of an end mill, the tooth rest and a cup wheel in the position where grinding is just about to begin is shown in Fig. 76. Incidentally the wheel is not quite so coarse as it appears in this photograph, it has been freshly dressed and the new grains have caught the light.

The basic "third position" in cutter grinding is shown in Fig. 77. Here the end teeth of cutter, in this case a ⅜ in. dia. end mill, are being ground. The shank of the cutter is held in a collet chuck and after one tooth has been set horizontal or what comes to the same thing, vertical by means of the long setting pin already shown in Fig. 69, the index plate is set to zero and locked. All further indexing is done by reference to it. That is to say if initially a tooth was set vertical it is only necessary to turn it through 90 deg. to establish a new zero in the next quadrant in which of course it will be horizontal. Successive teeth for cutters with 2, 3, 4, 6 or 12 teeth can then be brought into exactly the same position by using the appropriate holes in the index plate.

The tooth clearance angle is directly set by using the tilting bracket, here set over 5 deg. and thereby inclining the axis of the cutter by this angle to the always vertical face of the wheel. Before commencing to grind use the rocking lever and its fine adjustment screw to limit the travel of the work-head and the cutter as it is swung back and forth across the face of the grinding wheel so that, although the tooth being operated upon can be ground across its full face width, the next tooth cannot come into inadvertent contact with the periphery of the grinding wheel.

This is a particularly delicate adjustment with small 2-tooth slot mills where each tooth must be ground to the centre line but not beyond it otherwise the opposite tooth will be destroyed. Although the end teeth of end mills and the side teeth of side and face cutters are nominally square it is better if they are in fact ground slightly concave, say 1 deg. This is because the tips of the teeth do the most work and will wear down first. If they were absolutely square in the first place the very slightest amount of wear would cause the cutter to begin cutting on the heel of the teeth with a resultant

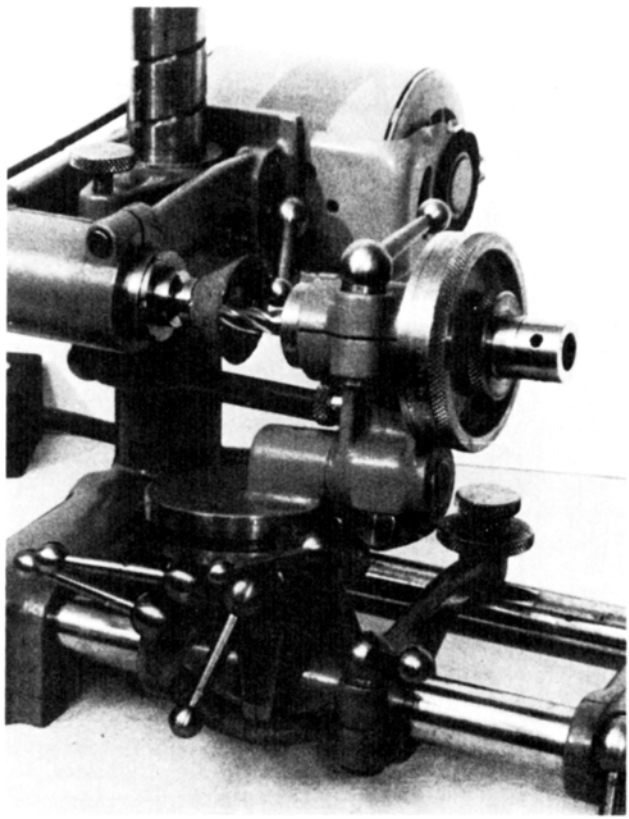


FIG 77 CUTTER GRINDING - END AND SLOT MILLS

WHEEL HEAD	*Axis parallel to base. Rotation upwards towards cutting edge.*
TOOTH REST	*Not used.*
FRONT BAR	*Free. Cut applied by micrometer screw.*
WORK HEAD BASE	*Clamped to front bar.*
ROCKING LEVER	*Set to limit cut towards centre of cutter.*
TILTING BRACKET	*Set to clearance angle.*
ROTATING BASE	*Set zero or minus 1° to give heel relief.*
TOOL HOLDER	*Collet chuck and index ring. Set one tooth vertical or horizontal with long setting pin. Set index ring to zero. Index either with holes, for sub-multiples of 12, or degree scale.*
METHOD OF OPERATION	*Advance the work towards the wheel under control of the front bar micrometer screw. Grind the tooth by rocking the work head up to the stop screw and back again. Swing clear and index and grind each successive tooth in turn. Apply the next cut, if required, by backing off the front bar micrometer screw. Secondary clearance, if required, is obtained by increasing the angle of the tilting bracket and re-grinding.*

loss in flatness of the work and freedom in cutting. By grinding the cutter slightly over square, wear makes it squarer and delays the time when it begins to cut on the heel. This adjustment can be very simply and accurately made by positioning the rotating base 1 deg. short of a true right angle. When all the adjustments are made and the settings locked the front bar is released and under control of its micrometer screw the first tooth ground. When it has cleaned up, the micrometer sleeve is set to zero, backed off and the next tooth ground to the same setting. This is one of the simplest and quickest operations in cutter grinding and takes little longer than grinding a twist drill, but with the Quorn the results are much more certain!

Fig. 78 shows a larger side-and-face cutter being ground in exactly the same manner, except that here the tooth rest is being used to index the teeth and it is being used inverted. This of course is quite easily done by fitting the entire tooth rest assembly to the vertical column above the wheel-head assembly instead of below it. Tooth clearance is again given by tilting the work-head but this time, because the cutter teeth are pointing upwards instead of downwards, clockwise instead of anti-clockwise. This particular cutter is a right and left handed one and is deliberately included as an example of more sophisticated cutter grinding. The face teeth for example cannot all be ground at a single setting. The machine must first be set up to grind say every alternate left-handed tooth. When they are finished it must be reset to grind the intermediate right-handed teeth. Because the tooth height setting will be lost in the process the height of the second set of teeth must be checked with a dial test indicator. Alternatively a witness may be ground on all teeth by cylindrical grinding and the two sets of teeth ground until the witness disappears.

A variation of the "first position" is shown in Fig. 79 in which an angle cutter is being ground. It is accomplished very easily by turning the rotating base to the required angle and locking it in position. Because the cutter diameter varies from tip to base the "second position" of grinding cannot be used and the limitations of a slightly curved clearance angle given by the "first position" must be accepted, otherwise the method of setting is the same as for a parallel sided cutter. This photograph also illustrates the use of the degree scale for indexing. Since the cutter has ten teeth for which there is no circle of holes in the division plate it is moved on 36 deg. on the degree scale each time to bring the next tooth to the grinding position.

Having mastered the intricacies of plain cutter grinding, which after all are not so intricate, we turn our attention to grinding ball nose and radiused cutters. Before this can be undertaken it is first necessary to set the machine so that the axes of the rotating base and of the work-head are exactly coincident. This is accomplished by the use of the long setting pin which fits in the hole in the rotating base and another pin which is held in a collet chuck in the work-head. The faces of both pins are brought into contact as in Fig. 80 and the position of the work-head locked. As a check the longer pin can be retracted, both pins turned through 180 deg. and re-engaged. This is a very sensitive test because if there is any error it will be doubled and the pins will either jam or have clearance between them. You can either split the difference if it is not too great, say less than 0.0015 in. when tested by a feeler gauge of this thick-

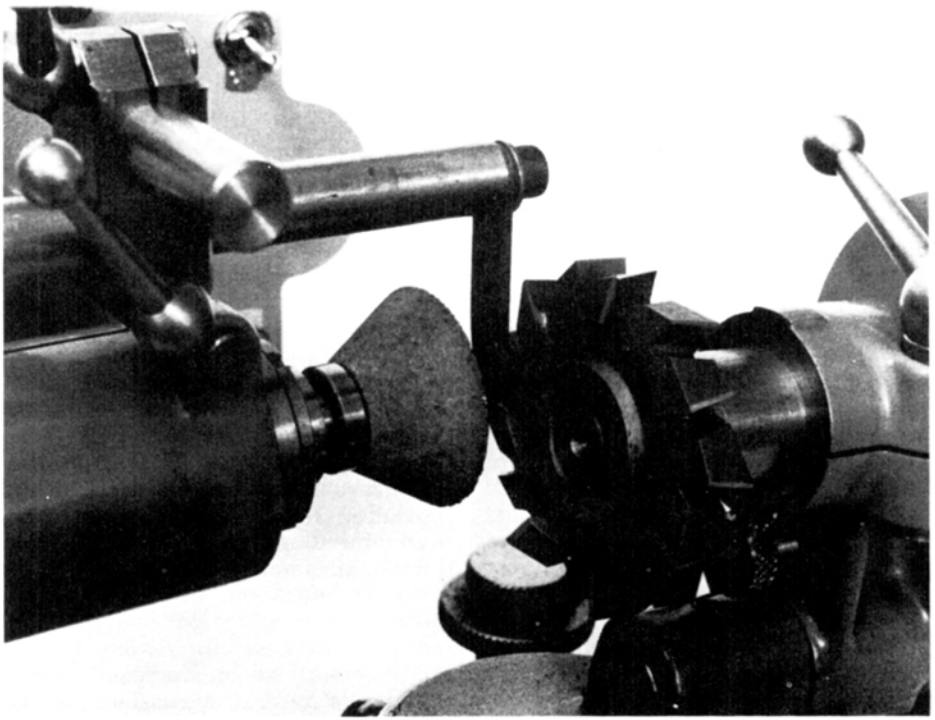


FIG 78 CUTTER GRINDING - SIDE AND FACE CUTTERS

WHEEL HEAD	*Axis parallel to base. Height to give clearance between teeth. Rotation against tooth rest.*
TOOTH REST	*Set to bring tooth horizontal. May be used inverted as shown.*
FRONT BAR	*Free. Cut applied by micrometer screw.*
WORK HEAD BASE	*Clamped to front bar.*
ROCKING LEVER	*Set to limit cut towards centre of cutter.*
TILTING BRACKET	*Set to clearance angle.*
ROTATING BASE	*Set zero or minus 1°, to give heel relief.*
TOOL HOLDER	*Mandrel to suit cutter to be ground. Dead mandrel with shoulder or live mandrel with stop collar. Tool holder bracket may be swung away from or towards wheel to accommodate larger or smaller cutters.*
METHOD OF OPERATION	*Advance work towards wheel under control of the front bar micrometer screw. Keep tooth firmly in contact with tooth rest and grind by rocking across face of wheel. Swing clear and grind each tooth in turn. Apply next cut, if required, by front bar micrometer screw. Secondary clearance by increasing angle of tilting bracket and re-grinding.*

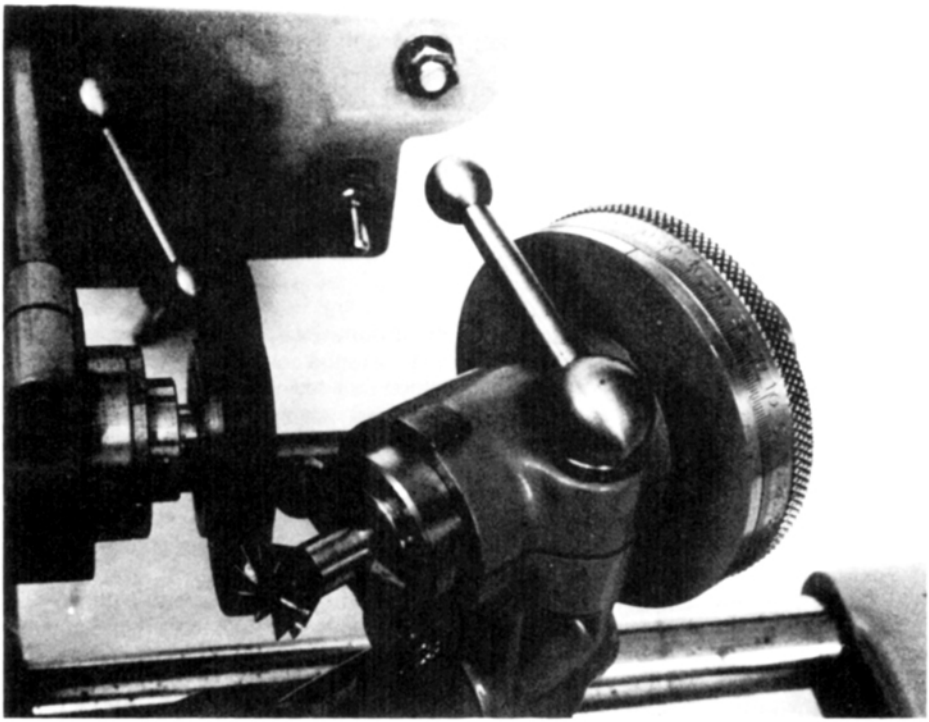


FIG 79 CUTTER GRINDING - DOVETAIL AND ANGLE MILLS

WHEEL HEAD	*Axis parallel to base. Height set according to page 89. Rotation, if index plate is used up against tooth face.*
TOOTH REST	*May be used for large cutter - see Fig 74. For small or fine tooth cutter not used.*
FRONT BAR	*Locked.*
WORK HEAD BASE	*Free to slide on front bar.*
ROCKING LEVER	*Set to bring work into contact with wheel. Cut applied by backing off micrometer stop screw.*
TILTING BRACKET	*Set zero.*
ROTATING BASE	*Set to required cutter angle.*
TOOL HOLDER	*As for Fig. 74 if tooth rest is being used. Collet chuck and index ring for small or fine tooth cutters. Set one tooth vertical or horizontal with long setting pin (see Fig. 90). Set index ring to zero. For sub-multiples of 12 use index holes. For other numbers use degree scale.*
METHOD OF OPERATION	*After locking all settings except work head base, slide entire workhead along front bar, keeping rocking lever stop screw firmly in contact with rear bar. Index and grind every tooth in turn. Apply next cut by backing off stop screw.*

ness, or look for the error elsewhere which may be in the straightness of the pins, eccentricity in the collet chuck or error in boring the hole in the rotating base. Once set, the work-head must not be moved again, but the setting pins can be removed and the cutter to be ground held in a suitable chuck as in Fig. 81. Clearance both front and side is provided by setting the tilting bracket to the required angle.

The rotating base is left free to turn but the stops are set at 0 deg and 90 deg. to prevent an over-shoot from damaging the side teeth of the cutter. Finally the cutter is slid forward in its collet until both tip and flank make equal contact with the grinding wheel as the rotating base is rocked through 90 deg. To accomplish this easily really needs another slide on the machine or the use of a setting micrometer, but with care it can be done without these aids. The actual grinding is quite straightforward and once one side of the ball end has been ground it is only necessary to index the cutter through 180 deg. to grind the other. Once the primary clearance has been ground on both teeth it is necessary to grind a secondary clearance at a much larger angle, 25 deg. to 30 deg., to prevent the heels of the teeth rubbing against the work. To do this it is only necessary to increase the angle of the tilting bracket, but first check that the primary clearance will not be ground out at any point and gradually reduce the width of the land until it is 0.010 in. to 0.015 in. wide, depending on the size of the cutter.

The width of land is best judged by eye, so familiarise yourself with professionally-ground cutters, or look at the edge of a feeler gauge. Incidentally, it is customary to grind a primary and secondary clearance on all cutters except fine tooth ones such as circular saws where the width of the primary clearance land is, or should be, very narrow anyway.

The "pons asinorum" of all cutter grinding, shunned by the professional as much as by the amateur, is radiusing the corners of a side and face mill or the ends of the teeth of an end or shell mill. Consequently they are left dead sharp and are an open invitation to the initiation of fatigue cracks in the sharp corners that they leave in the work. But the difference in the appearance of, say, a locomotive connecting or coupling rod which has been fluted with a cutter with radiused corners and one done with a cutter which has been left with a sharp corner is immediately obvious.

Radiusing the corners of a side and face mill is shown in Fig. 82. To bring the corner of the cutter, not its axis as in grinding a ball nose, into line with the axis of the rotating base, the centre line of the cutter must be displaced by swinging the work-head to one side. The long setting pin must be used, first to align both the side and face of the tooth with the axis and then to advance them beyond this position by an amount equal to the radius to be ground. Again it really needs a setting micrometer, but by checking against the face of the wheel which, used in conjunction with the front bar micrometer, really comes to the same thing, the job can be done. A special tooth rest blade, made from a broken hacksaw, with a narrow point, is being used here in the inverted position, because there is really very little room and the corner of the cutter only travels a very short distance in radius of a small circle. Clearance is provided as before by setting the tilting bracket and the stops on the rotating base, which is of course left free, are set to prevent overrun of the cut. Radiusing is not easy, but

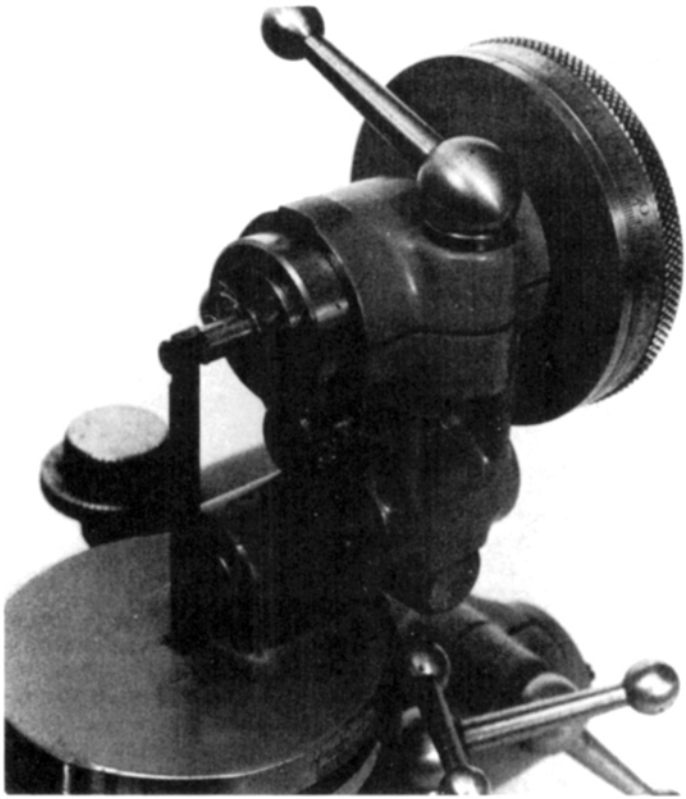


FIG 80 CUTTER GRINDING - BALL NOSE CUTTERS

Before a ball nose or semi-spherical cutter can be ground, the axes of the rotating base and the tool holder must be brought into alignment.

Insert the long setting pin into the hole in the rotating base and a short setting pin in a suitable collet in the indexing mandrel.

Free the tool holder bracket and the index ring and bring the two faces of the setting pins firmly together. Lock the tool holder bracket. N.B. This setting must not be disturbed until grinding is finished. As a check retract the long setting pin, turn it and the short pin through 180° and re-engage. There should be no clearance or interference.

Set the cutter to be ground in suitable collet chuck with its nose projecting beyond the face of the long setting pin by an amount equal to the radius plus a grinding allowance. This is most conveniently done with a setting micrometer.

Set one tooth of the cutter vertical against the face of the partially retracted long setting pin and the index ring to zero. Fully retract the setting pin and index through 90° before grinding.

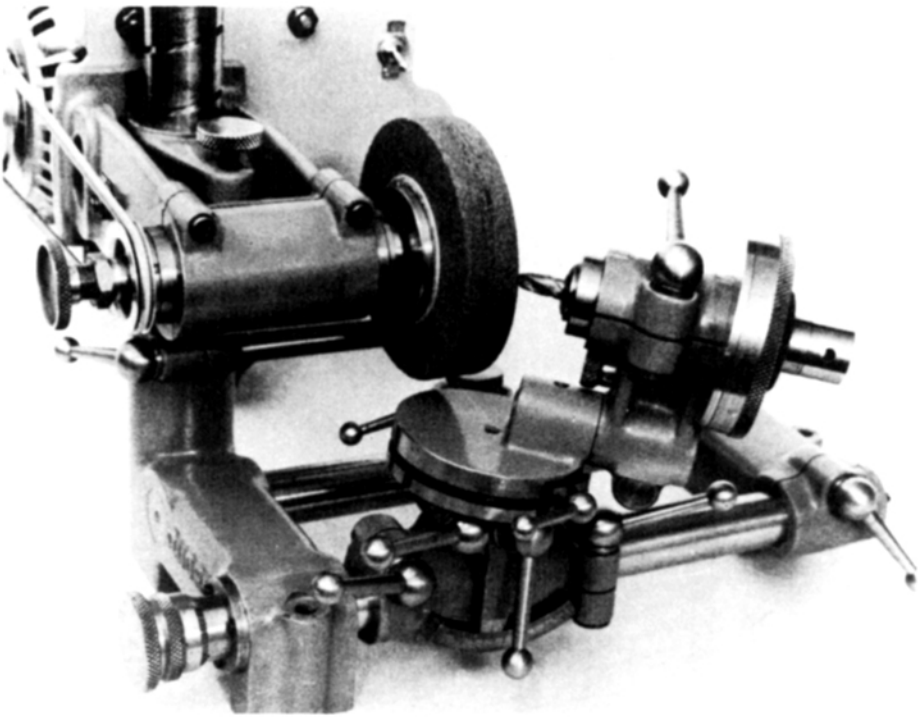


FIG 81 BALL NOSE CUTTERS

WHEEL HEAD	*Cup wheel. Axis parallel to base. Rotation downwards at front. Height unimportant.*
TOOTH REST	*Not used.*
FRONT BAR	*Free. Cut applied by micrometer screw.*
WORK HEAD BASE	*Clamp to front bar.*
ROCKING LEVER	*Set to centralise work on face of wheel.*
TILTING BRACKET	*Set to give clearance angle required.*
ROTATING BASE	*Free. Set stops to 0° and 90°*
TOOL HOLDER	*Aligned with rotating base as per Fig.80.*
MANDREL	*Collet to suit cutter and index ring.*
METHOD OF OPERATION	*Rotating base is swung between stops and advanced towards wheel by front bar micrometer screw. Cut must cease when radius blends with side of cutter Secondary clearance by resetting tilting bracket. One tooth usually ground past centre to avoid leaving a pip on the work. End faces of spirally fluted cutters to be ground square before radiusing.*

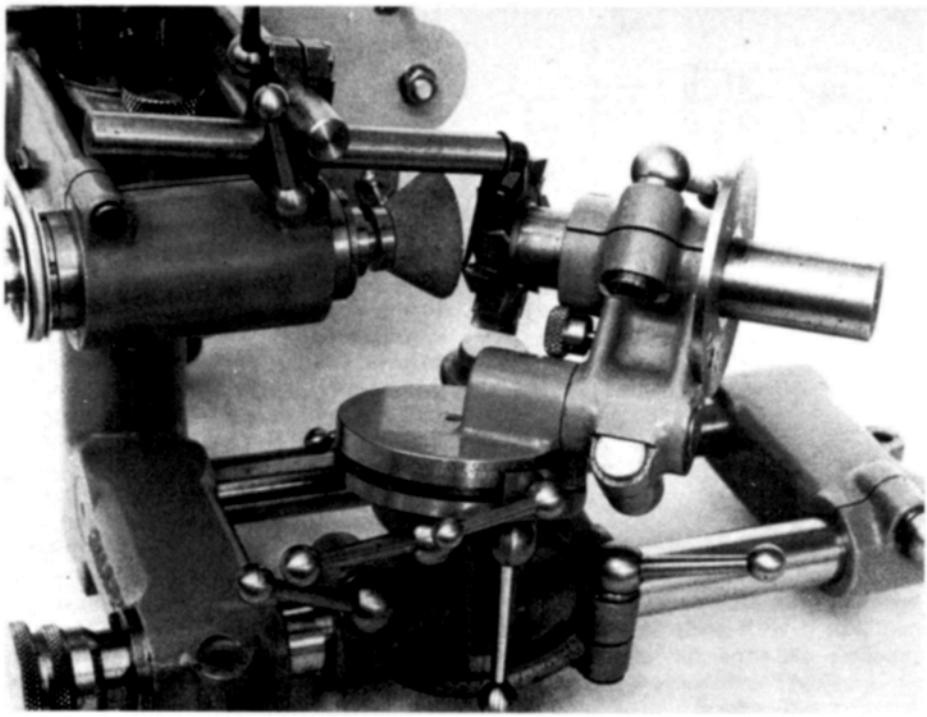


FIG 82 CORNER RADIUSING

WHEEL HEAD	*Cup wheel. Axis parallel to base. Rotation against tooth rest.*
TOOTH REST	*Set at centre height. May be used inverted. Narrow point desirable.*
FRONT BAR	*Free. Cut applied by micrometer screw.*
WORK HEAD BASE	*Clamped to front bar.*
ROCKING LEVER	*Set to centralise work on face of wheel.*
TILTING BRACKET	*Set to give clearance angle required.*
ROTATING BASE	*Free. Set stops to 0° and 90°*
TOOL HOLDER	*Offset to bring corner of cutter into correct relationship with axis of rotating base. Use setting pin or micrometer*
MANDREL	*To suit cutter. Index ring not used.*
METHOD OF OPERATION	*Swing rotating base between stops advancing work towards wheel by micrometer screw. Cut must cease when radius blends with side and face of cutter. Secondary clearance by resetting tilting bracket.*

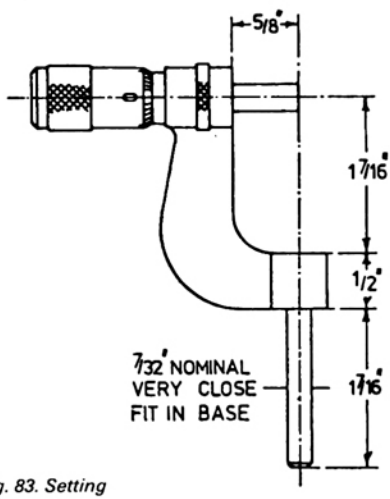


Fig. 83. Setting micrometer.

if you can produce a cutter in which the radii are all equal and perfectly blended with the sides and faces of the teeth you can take it with pride to the next club meeting and apply for full membership of The Royal and Ancient Order of Axe and Cutter Grinders!

All ball nose and radius grinding operations are enormously simplified if a radius setting micrometer is used – a feature not always to be found on even the most expensive commercial machines. Such a device, shown in Fig. 83, is not too difficult to make and well worthwhile if much radiusing work is to be done.

The micrometer head itself can either be bought out as a proprietary item or home made following the excellent series of articles written by Martin Cleeve in *Model Engineer* Vol. 130, p. 154 *et seq.* 1st March, 1964. ½ in. travel of the micrometer screw is enough since it will enable cutters up to 1 in. diameter to be set for ball nose grinding. In the case of a home-made micrometer screw there is no need to adopt the lead screw correcting device developed by Mr. Cleeve as a thread cut in the ordinary way will be quite sufficiently accurate. After all if one sets out to grind a radius of 1/16 in. no great harm will come if it is between 0.062 in. and 0.063 in. and over such a short distance any error in the screw pitch will be negligible.

Most important is the fit of the stem of the micrometer in the central hole bored in the rotating base. A considerable amount of overhang is inevitable so the stem should be hardened and lapped to a close fit in the hole. It can be fitted into the body of the micrometer either with 'Loctite' or as a press fit. The final adjustment is the zero setting and the sleeve should be adjusted until it reads zero both ways on a setting pin held in a collet chuck as in Fig. 80. A spindle lock on the micrometer screw is desirable, the micrometer being pre-set to the required radius, the spindle locked and each face of the cutter in turn being brought gently into contact with the tip of the micrometer screw. Thereafter it is only necessary to grind the radius until it blends with the other faces of the cutter.

CHAPTER 14

Miscellaneous and Special Purpose Cutters

Grinding and making very small cutters down to 1/16 in. dia. or less presents special problems. Engraving type cutters, which are really "D" bits backed off on the circular body so that they cut on the side as well as the end, are easy to make. They can be parallel or tapered and have square, radiused or ball nose ends. They cut quite freely in soft materials, but only having a single cutting edge are slower and weaker than a slot drill or end mill of the same size.

Grinding from the solid in hardened high speed steel is shown in Fig. 84. The cutter blank, which may be an ordinary round tool bit, is first reduced to diameter by ordinary cylindrical grinding using a plain disc wheel and rotating the work by hand. The spiral flutes are ground in by using the traversing mandrel and a suitable guide hob. The wheel in use here is an ordinary abrasive cut-off wheel 4 in. dia. purchased from the local D.I.Y. shop. Its use for cutter grinding is unconventional but dressed true it cuts very well and holds a good corner. The wheel-head is of course rotated to match the spiral angle of the cutter, but the actual setting of the wheel in relation to the cutter is difficult to describe in words. The plane of the wheel is offset in relation to the axis of the cutter so that one corner is deeper than the other. This produces a sufficiently deep cutting edge without unduly weakening the shank of the cutter. Perhaps the best thing to do is carefully to study a commercially-made cutter and then to try to reproduce the method of grinding. Once the setting is correct grinding the cutter is easy enough and it pays to make several at the same time– their lives are not all that long. By placing the wheel-head in the "first position" but without moving the cutter or the guide hob in the traversing mandrel the teeth of the cutter can be backed off both on the sides and ends in just the same way as the larger cutters. The adjustments are of course delicate, but by moving the guide pin bar and the front bar in conjunction with one another it will be found that the angular position of the cutter can be controlled with great precision.

Another use of the traversing mandrel is to grind screw threads in hardened material. In Fig. 85 a plain shank cutter is having a 3/8 in. by 20 t.p.i. thread ground upon it. The wheel is first dressed by one of the methods shown in Figs. 67 or 68 to an included angle of 55 deg. and a simple hob with a plain 20 t.p.i. thread used to guide the work. The tilting head is set to the spiral angle of the thread, in this case a shade under 2½ deg. To save excessive wear on the fine edge of the wheel the thread should be brought to nearly full depth in a single pass, rather than by a succession of light passes as

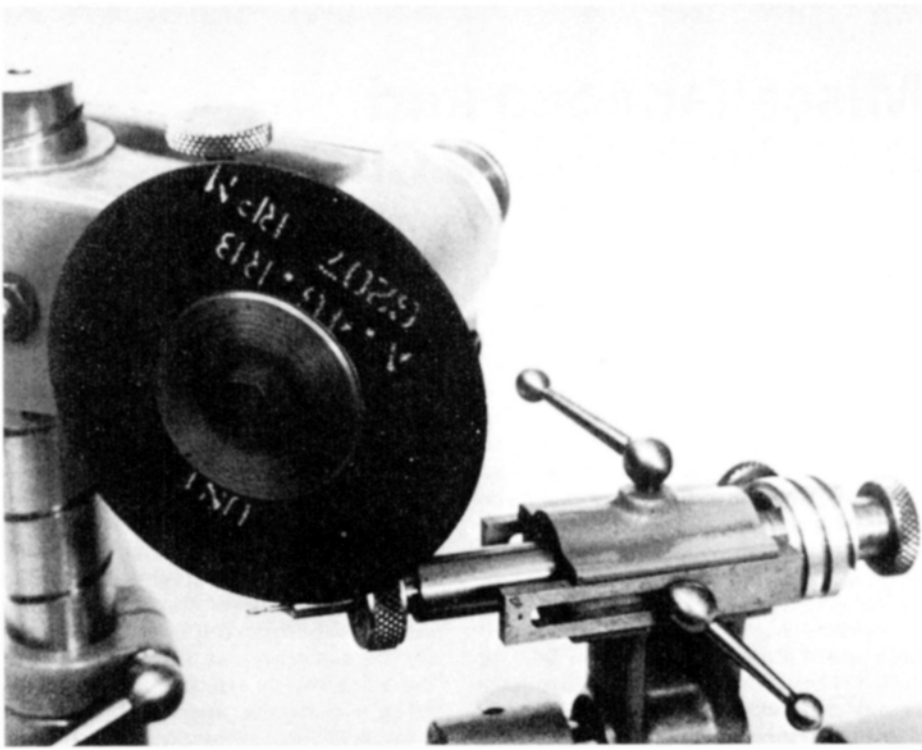


FIG 84 SMALL END MILLS AND SLOT DRILLS

WHEEL HEAD	*Narrow disc wheel. Axis inclined to spiral angle. Rotation outwards at bottom. Depth of cut by height adjustment.*
TOOTH REST	*Not used.*
FRONT BAR	*Locked.*
WORK HEAD BASE	*Clamped to front bar.*
ROCKING LEVER	*Not used.*
TILTING BRACKET	*Set zero.*
ROTATING BASE	*Set zero.*
TOOL HOLDER	*Spiralling head with traversing mandrel and guide hob. Set stop to length of flute.*
MANDREL	*To suit cutter and guide hob.*
METHOD OF OPERATION	*Flute formed by spiralling mandrel in and out. Retract and engage second thread to form second flute. Back-off as Fig. 74 using hob for guidance. End teeth formed as Fig. 77 and 81 using hob and stop for indexing.*

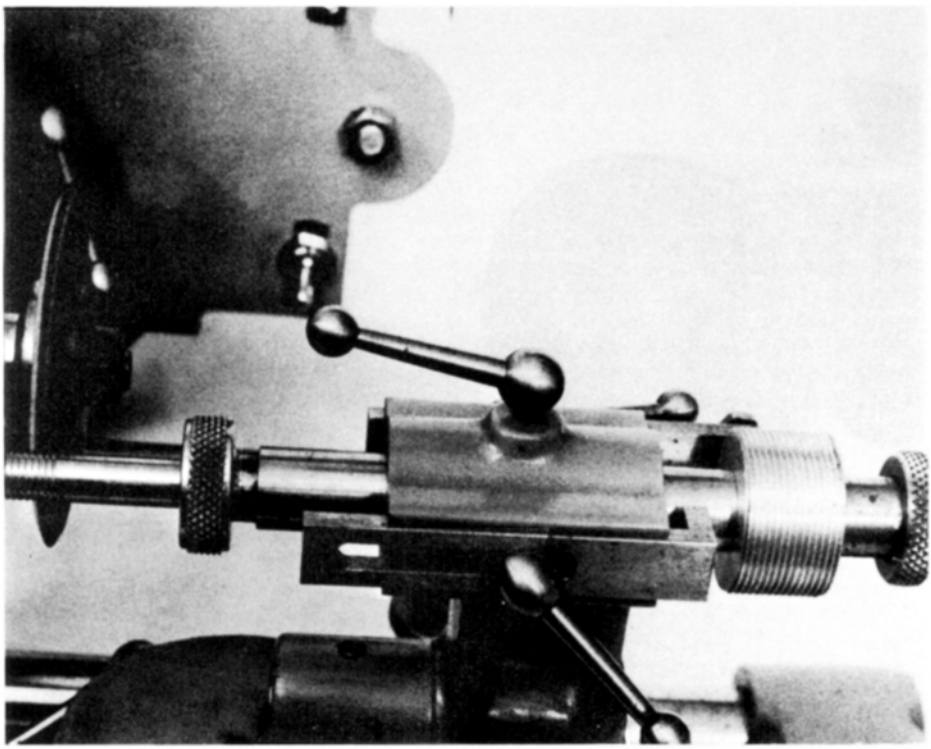


FIG 85 THREAD GRINDING

WHEEL HEAD	*Disc wheel dressed to thread angle - see Fig 67. Axis parallel to base. Rotation upwards at front.*
TOOTH REST	*Not used.*
FRONT BAR	*Free when setting, locked when grinding.*
WORK HEAD BASE	*Clamped to front bar.*
ROCKING LEVER	*Depth of cut controlled by stop screw.*
TILTING BRACKET	*Set to helical angle of thread.*
ROTATING BASE	*Set zero.*
TOOL HOLDER	*Spiralling head with traversing mandrel and guide hob. Set stop to length of thread.*
MANDREL	*To suit work and guide hob.*
METHOD OF OPERATION	*Advance work slowly against direction of rotation of wheel. Wheel may require re-dressing more than once before full depth of thread can be formed, e.g. from solid.*

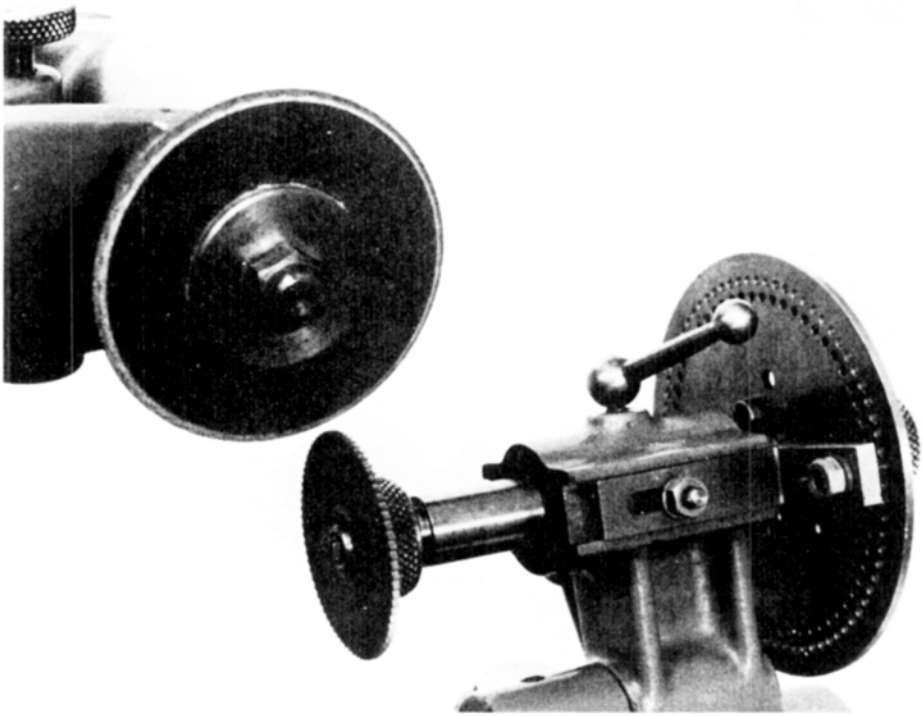


FIG 86 GULLETING FINE TOOTH SAWS AND FORM TOOTH CUTTERS

WHEEL HEAD	*Disc wheel dressed to included angle, see Fig. 67 for saws. Narrow saucer wheel for form and gear tooth cutters. Axis parallel to base. Rotation outwards at bottom.*
TOOTH REST	*Not used.*
FRONT BAR	*Locked.*
WORK HEAD BASE	*Free to slide on front bar.*
ROCKING LEVER	*Free to slide on rear bar.*
TILTING BRACKET	*Set zero*
ROTATING BASE	*Set zero.*
TOOL HOLDER	*Either but MUST have division plate with same number of divisions as cutter to be ground.*
MANDREL	*To suit cutter and division plate.*
METHOD OF OPERATION	*Face of cutter to be ground is set radial (form and gear cutters), hooked or negative rake (saws), with setting pin and straight edge. Cut applied by inching division plate and taken by sliding workhead along front bar, keeping rocking level stop firmly in contact with rear bar. Depth of gullet in saws controlled by wheelhead height adjustment.*

one would employ on a lathe. Quite apart from tool making the facility to grind threads could be a very useful one in general model engineering, in for example making high tensile studs from material too hard to be cut with a die.

Another use of the traversing mandrel is shown in Fig. 86 in which a fine tooth circular saw is being re-gulleted. This is an important part of reconditioning because although a saw is normally only sharpened at the tips of the teeth, with clearance of course, each sharpening reduces the size of the gullet. Comes a time then when the gullet is no longer big enough to contain the chip produced by the passage of the tooth through the thickness of the metal being cut and the chip, which has nowhere else to go, jams the saw in the cut.

The wheel is the same as that used in Fig. 85 but here re-dressed to an included angle of 60 deg. In dressing angle wheels it is not good practice to dress the face of the wheel only and to leave the side to produce the other side of the included angle. For one thing such a wheel is not easy to redress and for another the wear on the two faces will not be equal. The included angle, whatever it is, should be more or less equally divided between the two faces so that each does an equal amount of work. Such a wheel can nevertheless be used to grind radial or even undercut teeth by offsetting it until one face is radial to the axis of the cutter–a point easily checked by a setting pin and straight edge.

In gulleting a cutter or in grinding the radial teeth of a form cutter a tooth rest cannot be used because it cannot engage the tooth being ground. Attempts to index the cutter by engaging the tooth rest with another tooth are not likely to be successful because cumulative pitch errors will arise, particularly with cutters with large numbers of teeth. A positive and independent means of dividing is required and in Fig. 86 the same brass plate that was used for the engraving is being used again with a new ring of holes in it, but change wheels, regular division plates, in fact anything with the right number of divisions can be used if it is mounted on a suitable bush to fit the spindle. Even a spring loaded index pin is not necessary, just unlock the spindle, slide it back and re-engage the next hole or tooth. Grinding fine tooth cutters is a pleasant job for a quiet evening when one does not feel like any real work!

The machine performs an entirely different role when the long bar bed is in use and the work is ground between centres as in Fig. 87. As far as the wheel head and the tooth rest are concerned the setting is exactly the same as for the "first and second" positions which have already been described in detail and either may be used. But just as in the case of the top slide of a lathe, it is not sufficient to rely entirely upon the setting of a degree scale to ensure parallelism of long work. A further consideration is that as the tailstock has no means of locating it, it must, in any circumstances be set parallel. It is recommended therefore that before grinding, the centres be set true by mounting a parallel mandrel between them and using a dial test indicator. Once set, the tailstock should not be moved but work of various lengths can be placed between, and removed from, the centres by using the mandrel head, which is always parallel to the bed, as a working tailstock.

Of course it must be realised from the outset that a standard size reamer cannot be resharpened AND hold its nominal diameter. It is a moot point

whether it is better to have a blunt ½ in. reamer which does not cut, or a sharp reamer which is 0.002 in. undersize. Since most reamers are mainly used to produce a round and parallel hole to w ich a turned part is subsequently fitted the latter is probably the better strategy and with the metric system maybe we shall be able to regrind our worn fractional inch reamers to the next smallest metric size!

Just as it is easier to turn taper than parallel, so by setting the rotating base to an appropriate angle, taper reamers can be ground and the lead ground on parallel ones. Grinding between centres can also of course be applied to any tool or cutter which has good centres at both ends as an alternative to chuck or arbor mounting.

Until the advent of the Quorn, small taps like small cutters were seldom sharpened during the course of their working lives and finish up blunt or broken. In Fig. 88 a tap is being sharpened along the length of its flutes. This method of sharpening, which can also, be applied to reamers if they are not too badly worn, does not reduce the effective diameter, since they have no clearance, and can be repeated until the lands are too thin to withstand the force of cutting. Indeed a tap cuts more freely if the lands are relatively narrow and some new but not too well made taps, especially fine pitch ones, would be the better for a bit of metal off the lands before ever they were used. Taps and reamers that are too small to have a female centre in them are nearly always left with male centres at the ends and can therefore be mounted between female centres as in Fig. 88. Here a small plain disc wheel with the edge dressed to radius is being used to grind the flute and to provide clearance at the run-out over the half centre at the right hand end. Because the flute is deep and accurate indexing is not essential, it is sufficient to keep the leading edge of the tap up against the face of the wheel by finger pressure alone as the work is traversed back and forth.

Taps are normally ground with a small positive angle or 'hook' to the cutting edge of between 5° and 7°. This is obtained by off-setting the face of the grinding wheel from the centre line of the tap, the amount of the off-set being exactly the same as that given in Table 2 on page 94 for grinding cutters with a disc wheel. Once set the off-set must not be changed but the cut applied by rotating the tap about its axis. For small work this can be done by hand but for larger work it might be preferable to set up and use the indexing head, holding the shank of the tap in a chuck or collet or if between centres driving it by a bent tail carrier and catch plate.

The answer to the sixty-four thousand dollar question: will the Quorn sharpen twist drills is both YES and NO. If suitable collets are available it will sharpen twist drills by the "four facet" method. It will not sharpen drills by the conventional continuous back-off method without a special fixture which has not yet been made or tested.

Since the "four facet" method may not be widely known, indeed it is only just finding acceptance in industry where it is claimed that it not only enables a drill to be started more accurately, even without a centre-pop, but that it gives a straighter hole with less tendency to wander and more closely to size, it is therefore worth devoting a few words to the system before attempting to describe how drills are sharpened to comply with it. Like most grinding jobs it is easier to demonstrate them to describe it, but Fig. 89 attempts to show

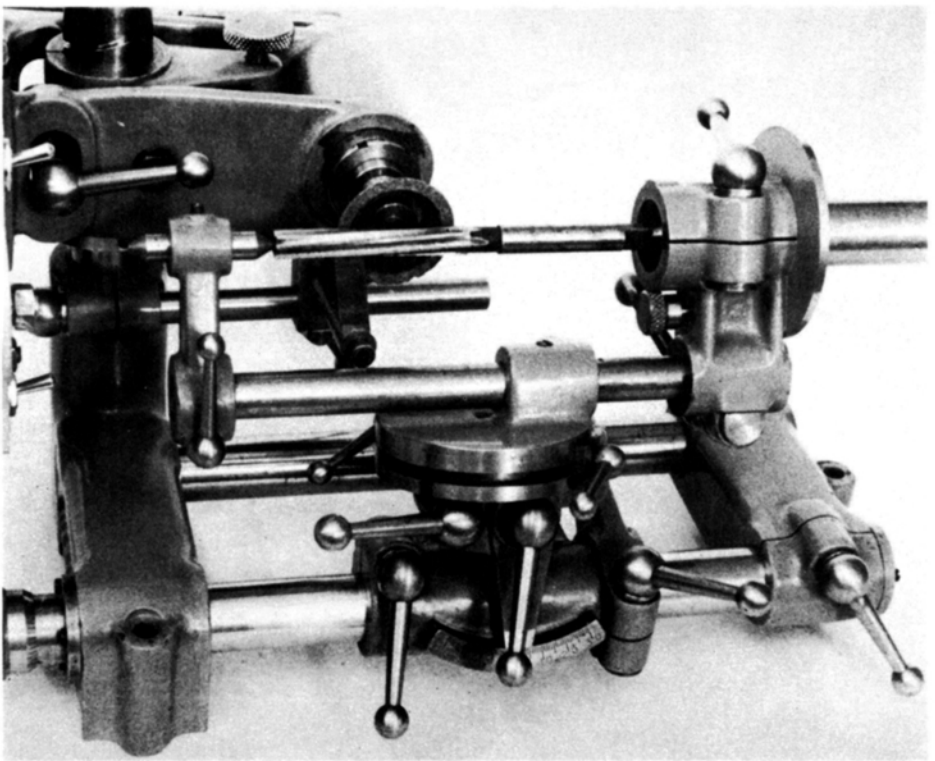


FIG 87 REAMERS AND LONG CUTTERS

WHEEL HEAD	*May be parallel to base, disc wheel (see Fig. 74), or at right angles, cup wheel (see Fig 76). Rotation downwards towards tooth rest.*
TOOTH REST	*Height set to give clearance angle required, (see page 89).*
FRONT BAR	*Locked.*
WORK HEAD BASE	*Free to slide on front bar.*
ROCKING LEVER	*Free to slide on rear bar.*
TILTING BRACKET	*Set zero*
ROTATING BASE	*Set zero for parallel reamers. Set to half included angle for taper reamers and cutters. N.B. It is advisable not to rely upon the degree scale for accurate setting but to take a trial cut or set with a test bar and dial gauge.*
TOOL HOLDER	*Long bar bed with tailstock and either tool holder as headstock.*
MANDREL	*Any with male or female centres.*
METHOD OF OPERATION	*Workhead slid along front bar keeping rocking lever stop firmly in contact with rear bar. Depth of cut by backing off rocking lever stop screw and re-locking.*

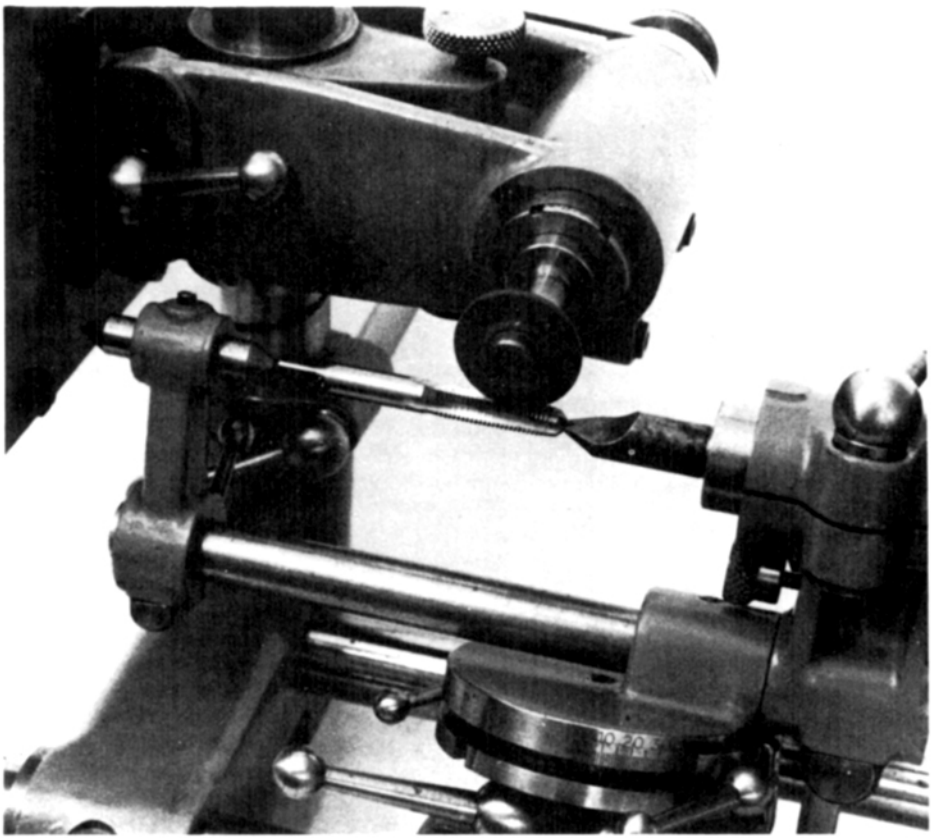


FIG 88 TAP SHARPENING

WHEEL HEAD	*Narrow disc wheel, radius dressed, see Fig. 68. Axis at right angles to base. Rotation towards work.*
TOOTH REST	*Not used.*
FRONT BAR	*Locked.*
WORK HEAD BASE	*Free to slide along front bar.*
ROCKING LEVER	*Free to slide along rear bar.*
TILTING BRACKET	*Set zero.*
ROTATING BASE	*Set zero.*
TOOL HOLDER	*Long bar bed with tailstock and either tool holder as headstock.*
MANDREL	*Any with male or female centres.*
METHOD OF OPERATION	*Workhead slid along front bar keeping rocking lever stop screw firmly in contact with rear bar. Sides of flute kept in contact with grinding wheel by finger pressure.*

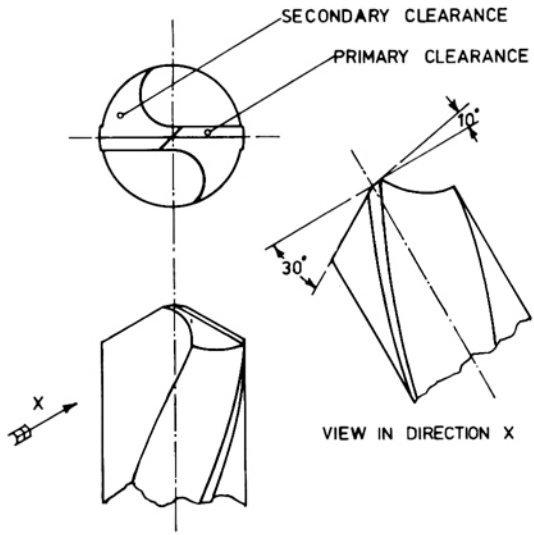


Fig. 89. 4-FACET DRILL POINT

what the point of a drill ground by the four-facet method should look like when it is finished. Instead of one continuous conical back-off angle the cutting edge is ground with a primary and secondary clearance angle just like an end mill in fact. The important difference is, however, that the secondary clearance is taken just so far that the back edge of the primary clearance on both lips of the drill forms an exact straight line across the diameter of the drill. The nett result of this is that the chisel point, instead of being straight and at right angles to the axis of the drill, is itself pointed, albeit to a very slight amount. It is this minute difference which gives the drill its self-starting and true running properties. In other respects the point geometry is normal, that is to say the point angle is the customary 118 deg., the primary clearance angle between 10 deg. and 12 deg., and the secondary clearance between 25 deg. and 30 deg., but need only be so much as to prevent the heel of the drill rubbing on the bottom of the hole. The arris angle, usually given as 45 deg., looks after itself.

Given therefore an accurate collet of a size to suit the drill to be ground the first operation is to bring the lip of the drill horizontal by the use of the setting pin as in Fig. 90. If the lip of the drill is very badly ground or broken it may be necessary to make an approximate preliminary setting and after a more respectable lip has been restored to repeat the setting with greater precision. Once the setting has been established, however, and the index plate set to zero, all further angles will be established by reference to the machine scales. In this position the setting pin cannot be removed but it can be pushed down out of the way of the grinding wheel.

The primary clearance is ground first,

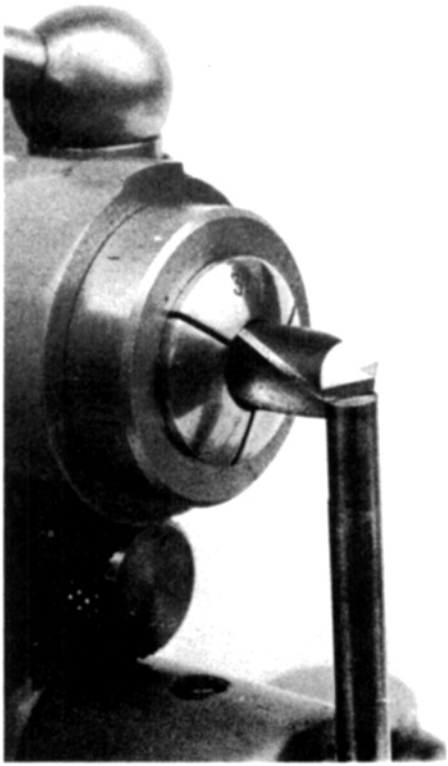


FIG 90 TWIST DRILL SHARPENING
4 FACET METHOD

PRELIMINARY SETTING

Hold drill in true running collet chuck with minimum overhang.

Free tool holder and mandrel locks and align lip of drill with setting pin.

Lock tool holder and mandrel. Set index ring to zero. Free mandrel lock. Retract setting pin.

as in Fig. 91, by setting the rotating base to half the point angle, that is 31 deg. from zero and the tilting bracket to the clearance angle required, usually 10 deg. or 12 deg. With all settings locked but the front bar free the cut is taken, as usual, by rocking the workhead across the face of the cup wheel whilst at the same time advancing the work under control of the micrometer screw. When the first lip has cleaned up, set the micrometer index to zero, retract the work, index the drill 180 deg. and grind the second lip to exactly the same setting.

The secondary clearance is ground in exactly the same manner merely by increasing the angle of the tilting bracket to between 25 deg. and 30 deg. Once the line of intersection between the primary and secondary planes has been established by a few trial passes, it may be necessary to rotate the drill slightly to bring this line parallel to the lip of the drill. This can be done by withdrawing the index pin and using the degree scale for indexing, but not more than 2 deg. or 3 deg. should be necessary. Grind each lip in turn and proceed with caution as the lines of intersection approach one another, aiming to stop when they are exactly in line. If you overdo it not to worry, return to the primary angle setting and give the lips the lightest

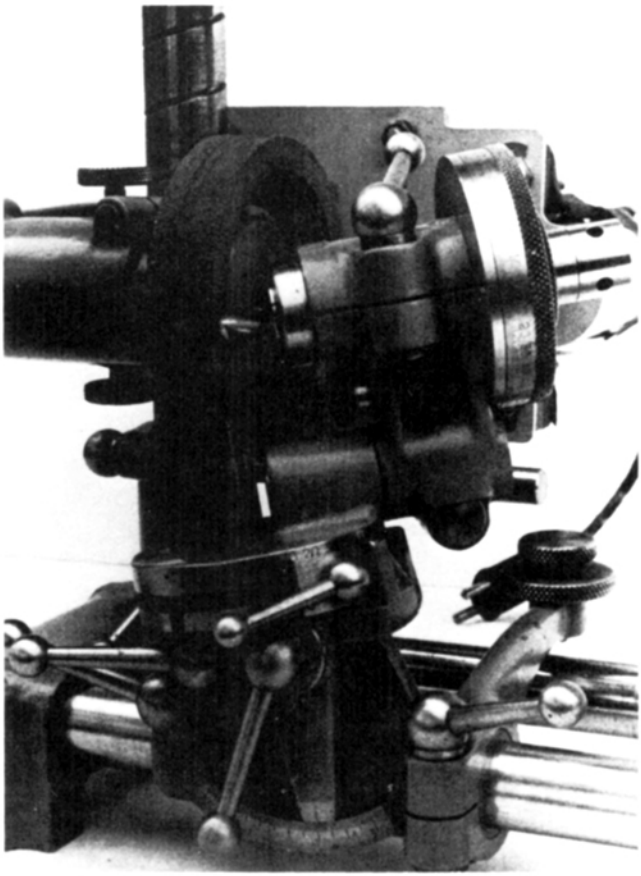
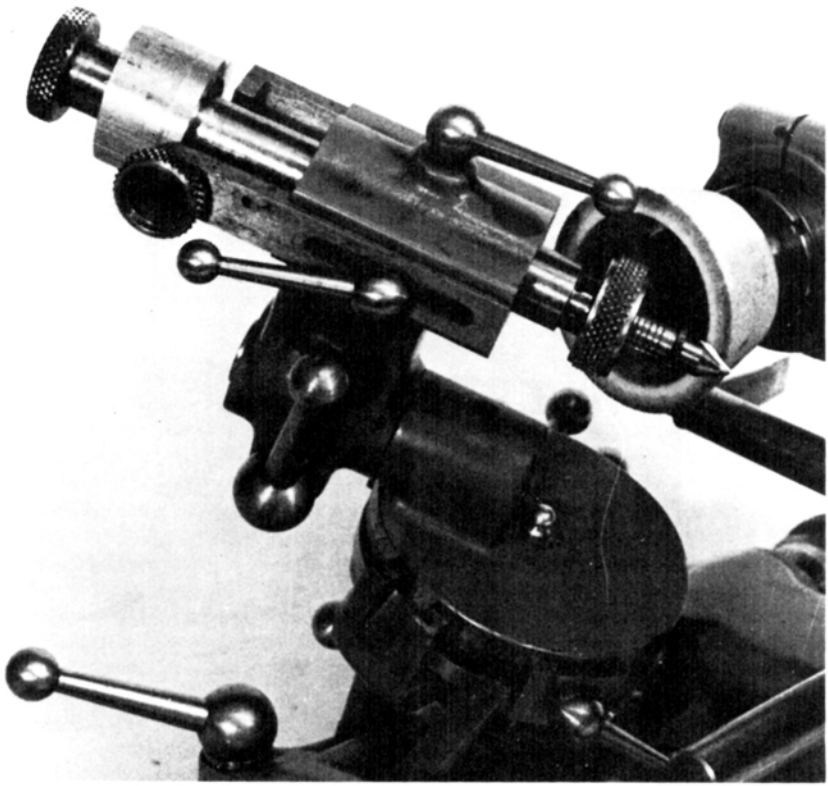


FIG 91 TWIST DRILL GRINDING - 4 FACET METHOD

WHEEL HEAD	*Cup wheel, axis parallel to base. Rotation upwards at front.*
TOOTH REST	*Not used.*
FRONT BAR	*Free.*
WORK HEAD BASE	*Clamped to front bar.*
ROCKING LEVER	*Set clear.*
TILTING BRACKET	*Set to clearance required, 10° primary and 30° secondary clearance.*
ROTATING BASE	*Set to complement of half point angle normally 31°.*
TOOL HOLDER and MANDREL	*See Fig 90 for setting instructions.*
METHOD OF OPERATION	*Swing workhead across face of wheel applying cut by means of front bar micrometer screw. Index 180° and grind second lip at same setting. Re-set tilting bracket to second clearance angle and grind until intersection of the two lands is exactly across the centre line of the drill.*

THE QUORN



WHEEL HEAD	*Small cup wheel. Axis parallel to base. Rotation downwards at rear.*
TOOTH REST	*Not used.*
FRONT BAR	*Locked.*
WORK HEAD BASE	*Clamped to front bar.*
ROCKING LEVER	*Not used.*
TILTING BRACKET	*Set zero.*
ROTATING BASE	*Set 30°.*
TOOL HOLDER	*Spiralling head with traversing mandrel and guide hob.*
MANDREL	*To suit drill and guide hob.*
METHOD OF OPERATION	*Set drill so that point is clear of far side of wheel. Apply feed by advancing hob guide pin. Rotate between stops to form and back-off conical lips. Form point as Fig. 91. Reform flutes as Fig. 86.*

possible kiss to widen the land width the required amount, how romantic that sounds!

There can be few model engineers who have not at some time or another brok n the point off a centre drill, first at one end, which is not too bad, and then at the other which leaves one with a stump of high-speed steel for which there is little use except to make cutter bits for boring bars. It is however an expensive way of providing cutter bits and it would be much better if the broken point could be reformed. This cannot be done by hand, at least the writer cannot do it, nor is it always possible even with a regular twist drill grinder. It seemed a good idea therefore to see if the Quorn would do it, there being plenty of experimental material available since the writer is a magpie and never throws away anything.

The crux of the problem is to find a way of grinding back the conical portion of the drill, still keeping the 60 deg. included angle and a proper back-off, but at the same time leaving the centre unground to form the substance of a new point. The basis of the method is shown in Fig. 92. The drill is held in one of the traversing mandrels, but instead of making a new mandrel to suit each size of centre drill, a series of split sleeves were made, bored to suit the size of drill and turned externally to suit one of the other of the traversing mandrels, the 1/4 in. one taking the smaller sizes and the 3/8 in. one accommodating the rest. To give the in-and-out motion necessary to back-off the cutting edges of the drill the other end of the traversing mandrel is equipped with a face cam which is interchangeable with the guide hobs normally used with the traversing mandrel. Strictly there should be a face cam for each size of drill and the curve should be a helix, but the writer found that straight cuts, filed or milled, of two different heights suited standard centre drills in the size range from 1/8 in. to 3/8 in. dia.

The cam face engages the guide pin normally used with the spiralling hobs so that as the mandrel is turned it also moves slighly backwards and forwards thus giving back-off to the centre drill being ground. The steps at the end of each cam face prevent the mandrel and the work being turned more than 180 deg. and so the opposite lip of the drill coming into inadvertent contact with the grinding wheel.

To produce the 60 deg. included angle, or any other angle for that matter, the rotating base is set over the half that amount and locked. The nub of the matter is now to set the work up in relation to the grinding wheel so that although the conical lips of the drill can be ground, material will be left at the centre which will form the pilot which is the essential characteristic of all centre drills. This is done, as is clearly shown in Fig. 92 by setting the work so that the tip of the drill extends beyond the far side of the face of the grinding wheel and hence is not ground by it. To obtain clearance a fairly small wheel must be used and here the writer is using a 2 in. cup wheel with the face dressed true and a sharp edge since this is really a form grinding operation in which the angle of the conical lips and a clean transition between them and the pilot part of the drill depend on the shape of the wheel.

The cut is applied by advancing the bar carrying the guide pin, all other motions being locked, so that the mandrel is advanced along its length until sufficient material has been ground away from the conical lips of the drill to form a new pilot. Each lip is of course

ground in turn merely by retracting the mandrel before engaging the other cam face. Movement of the bar carrying the guide pin between cuts must be done with discretion. It would be nice if it were screw controlled, but not essential because even if too much cut is applied it need not be removed in a single pass. Under hand pressure several passes can be made on each lip of the drill until the wheel sparks out.

When sufficient material has been ground off the conical lips to leave a new pilot of sufficient length, usually length equal to diameter and ranging from 3/64 in. to 1/8 in. for the sizes of centre drill under consideration, a new point can be formed on the pilot, either by free-hand grinding, in a regular twist drill grinder, or by the 4-facet method described earlier. A 4-facet centre drill really is something which as far as I know cannot be bought. It may be, and certainly would be if the operation were repeated more than once, that the flutes in the centre drill will no longer be long enough to form a complete conical lip and to provide for the escape of chips when the drill is sunk to its full depth. This can be easily rectified in a second operation in which the drill, held in the indexing workhead with its axis parallel to the base of the machine, is presented to the lower edge of a disc wheel with its axis at right-angles. In this way the points at both ends of the drill can be reformed until they meet in the middle which is perhaps the most economical way of using high-speed steel that anybody could devise!

The subject of sharpening taps has been dealt with in some detail, but nothing has been said about the equally important matter of sharpening dies. The problem here is to have a small enough wheel, a point really, to go inside the cut-out of a die and to be able to rotate it fast enough to have some semblance of a cutting rather than a rubbing action. The A13 spindle bearings in the Quorn wheelhead have a maximum rated speed of 15,000 r.p.m. and to drive the spindle at this speed as shown in Fig. 93 a light wooden pulley 7 1/4 in. dia. was mounted on the driving motor shaft. This size pulley can only be fitted to the Mk I wheelhead. Having a love for pattern making the writer makes pulleys like this the "proper" way, namely from three layers of laminated segments overlapping and with the grain running radially. They are really much easier to make this way rather than by looking for a piece of wood free from knots and shakes big enough to turn a pulley from the solid, but there is no reason why a metal pulley should not be used provided it was as light as possible and well balanced. The belt speed, 5645 ft/min., is on the high side for the "Roundthane" belt in use but it survived. It would however be too high for a black plastic belt.

The "point" shown in Fig. 94 is made from a piece broken off a carborundum slip stone 1/4 in. dia. by 3 in. long. It is cemented into its carrier with shellac rather than epoxy because sooner or later, and probably sooner rather than later, it will be broken and have to be replaced by another piece of the slip stick of which there is plenty left. With shellac it is only necessary to warm the holder, shake out the broken stump and put in a new piece with a little more shellac, all at the same heat. After mounting, the point is of course dressed true with a diamond in the usual way.

To hold the dies, an ordinary die holder cannot of course be used because it is not the concentric threaded portion that we wish to grind but the

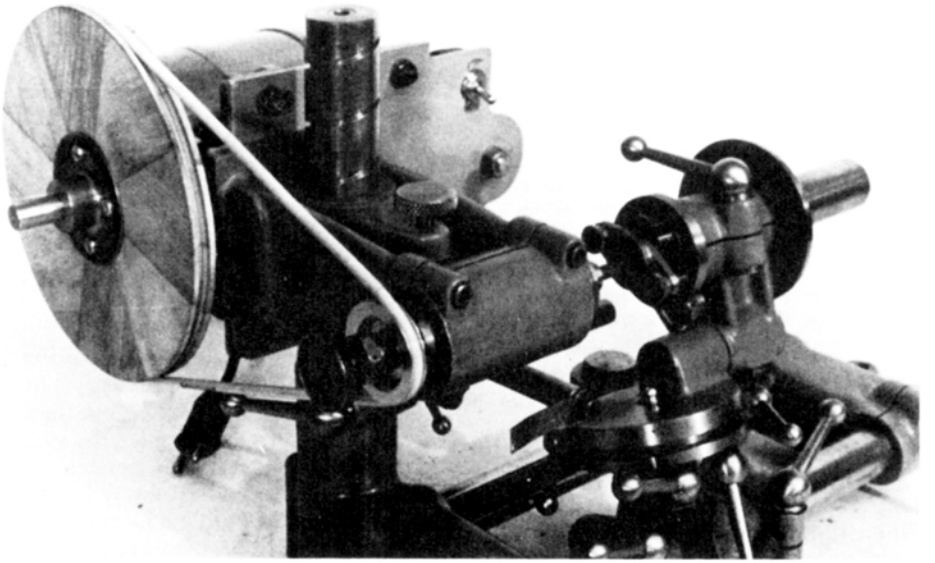


FIG 93 SCREWING DIES

WHEEL HEAD	*Pencil wheel or point. Large pulley to give maximum rated spindle speed 15,000 r.p.m. Axis parallel to base.*
TOOTH REST	*Not used.*
FRONT BAR	*Locked when grinding. Free when setting.*
WORK HEAD BASE	*Clamped to front bar.*
ROCKING LEVER	*Set to limit depth of cut.*
TILTING BRACKET	*Set zero.*
ROTATING BASE	*Set zero.*
TOOL HOLDER	*Die grinding attachment.*
MANDREL	*Free to slide and turn.*
METHOD OF OPERATION	*Apply cut by backing off rocking lever stop screw. Rotate and slide mandrel back and forth by hand. N.B. Only very light cuts can be taken or the pencil wheel will be broken.*

REMOVE THE LARGE PULLEY BEFORE USING LARGER WHEELS

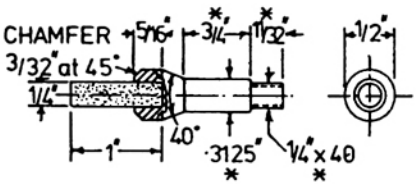


Fig. 94. GRINDING POINT 1 OFF
M.S. & CARBORUNDUM

*N.B. Dimensions marked * must be modified to suit 8 mm collets.*

eccentric holes which where they intersect the central threaded hole, form the cutting edges. A simple carrier shown in Fig, 95 in the form of a miniature faceplate with a bridle enables the die to be clamped to it with the hole to be ground concentric with its axis. To assist in centring the hole the body of the holder is hollow and carries a pump centre with a blunt point. By centring the hole in the die on the point of the pump centre and then tightening the bridle it is located sufficiently accurately for grinding. The pump centre is of course removed before grinding. The die holder has a short tail which fits any of the mandrels with which the machine is equipped; that shown is a stub No. 2 Morse which fits the corresponding mandrel.

The machine is set so that the grinding point will enter the hole in the die as centrally as possible and the cut applied by rocking the entire workhead either backwards or forwards under control of the micrometer screw at the end of the rocking lever. Of course only very light cuts can be taken as the mandrel carrying the die in its holder is slowly rotated by hand and slid backwards and forwards to use more of the surface of the grinding point. Either the whole of the hole may be ground and with it of course the actual cutting or the die hole may be set slightly eccentric so that only the cutting edges themselves are ground. The latter involves less grinding but is slightly more difficult to set up.

The carrier shown will accept dies up to 1 5/16 in. dia. and these are the easiest to resharpen because the holes in them are relatively large, but the writer must admit that he has not yet found a way of resharpening 10 BA dies, some of which have holes only 3/32 in. dia. in them.

The high-speed spindle with a small point in it is of course of general utility in grinding small internal radii in any tool, gouges, boring bits and the like, and makes a splendid job of nicking the edge

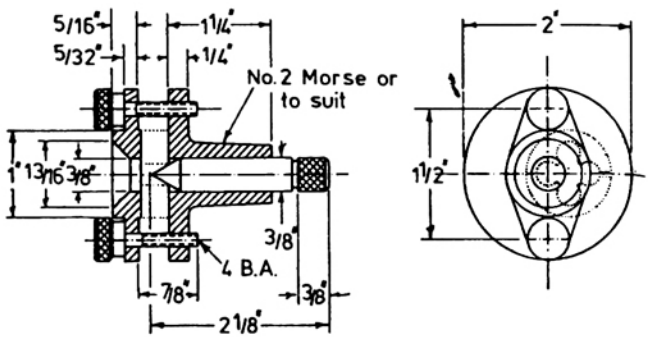


Fig. 95. DIE CARRIER 1 OFF MILD & SILVER STEEL

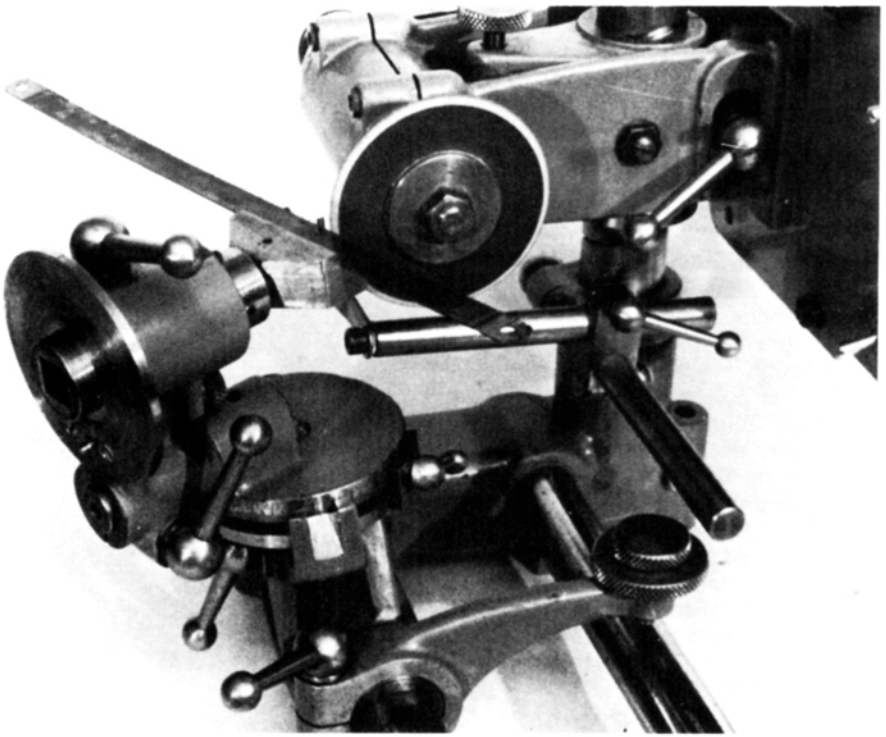


FIG 96 SAW SHARPENING

WHEEL HEAD	*Disc wheel, dressed to included angle, see Fig. 67. Axis parallel to base. Rotation downwards at front.*
TOOTH REST	*Not used.*
FRONT BAR	*Free.*
WORK HEAD BASE	*Clamped to front bar.*
ROCKING LEVER	*Set to limit depth of cut.*
TILTING BRACKET	*Set zero.*
ROTATING BASE	*Set to give required tooth angle, normal, hooked or negative.*
TOOL HOLDER	*Saw grinding attachment with spring detent.*
MANDREL	*Clamped in tool holder.*
METHOD OF OPERATION	*Engage detent in second saw tooth and grind first tooth by rocking workhead to fixed stop. Lift rear of saw blade and engage detent with third tooth. Grind second tooth etc. N.B. The last tooth cannot be ground this way and must either be finished free-hand or omitted. All teeth of a band saw can however be ground in one operation.*

of a parting tool to give it top rake because the grinding marks run away from the cutting edge instead of across it. The work may be done in the machine or off-hand, but the writer finds that because of the versatility of the wheels that may be used with the Quorn and because of the speed with which they may be changed, he now does a lot of off-hand work on it in preference to using the bench grinder which, except for heavier work, could now be pensioned off.

Although most hacksaw blades end their lives by breaking before they are seriously blunted some survive and there may be occasions when a really sharp blade would be a godsend in sawing slippery material like brass and phosphor bronze. Hacksaw blades may be sharpened using the set-up shown in Fig. 96 and the blade carrier detailed in Fig. 97. The carrier has a square shank which enables it to be held in the tool holder and an adjustable fence to accommodate various widths of blade from machine blades down to miniature saw blades. The heart of the device is the spring-loaded detent which engages a tooth next to the one being ground and so makes the positioning of the teeth in relation to the grinding wheel self-indexing.

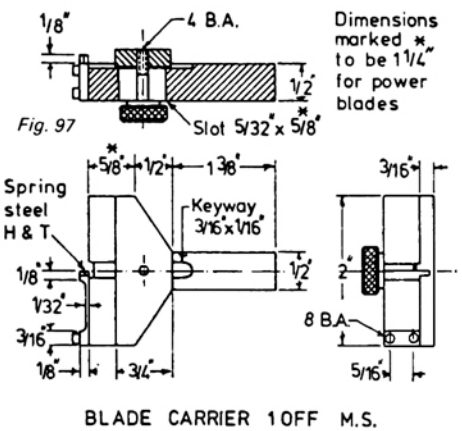


Fig. 97

BLADE CARRIER 1 OFF M.S.

In use, the fence is set so that the blade is firmly held against the detent which springs slightly to accommodate it. Engaged in the last tooth but one the work is brought up to an angular dressed wheel at approximately centre height. The rake on the cutting teeth, which may be positive, negative or neutral depending on the use to which the saw is going to be put, is set by turning the rotating base. The depth of cut, sufficient to clean up the worst worn tooth, is controlled by the rocking lever micrometer and taken as a plunge cut by rocking the centre workhead and with it the work towards the wheel. Once one tooth has been ground it is easy enough to lift the blade at the rear, disengage it from the detent, engage the next tooth and press the blade back into position. It is a tedious operation, especially with a fine tooth blade, and of course the last tooth cannot be ground because there is no following tooth to locate it, but the writer finds that he seldom makes use of the last tooth!

Resharpening a worn hacksaw blade may seem a waste of time and energy, and so in the ordinary way it would be. But a ground tooth blade, new or reconditioned, is so incomparably sharp, even in comparison with a new blade, that the writer keeps one in a spare frame for special jobs and woe betide anyone who uses it for sawing black iron or tiles! Blade sharpening really comes into its own with bandsaw blades and here of course the problem of the last tooth does not arise and as the writer is a constant user of his "Burgess" band saw for both wood and metal cutting, the blade grinding attachment has

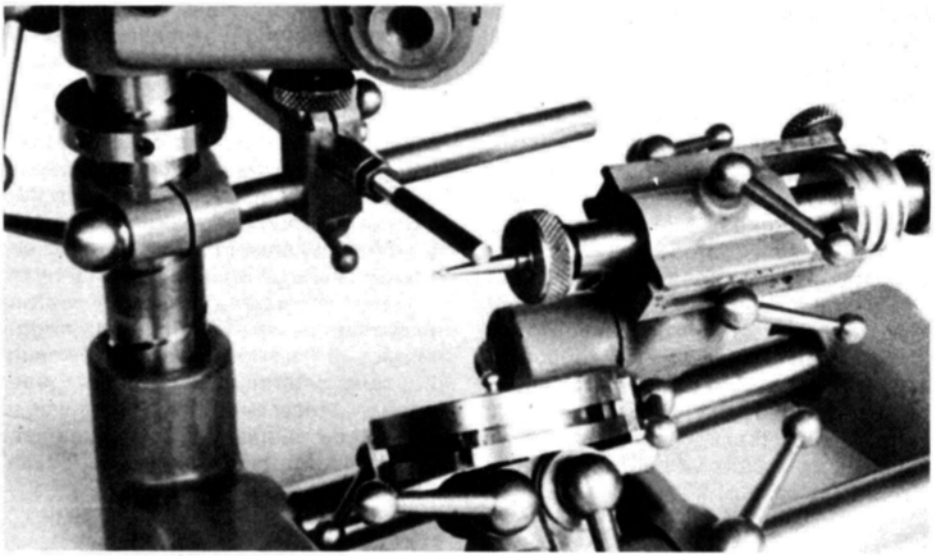


Fig. 98. Setting for a spirally fluted tapered end mill.

been well worth while making, even if it does not put any "set" on the blades.

The ability to make special purpose cutters is an essential feature of the Quorn and was recently tested to some purpose in making a tapered end mill with a 10 deg. included angle and a ball nose 0.012 in. radius. The first cutter to be made was in the form of an engraving cutter, that is a backed-off "D" bit with tapered sides and a rounded point. It cut well enough, but was very frail and liable to choke when sunk to the full depth of 1/8 in. and despite considerable care in use and light cuts broke before the job was complete. The second cutter was spirally fluted like a normal end mill but because the flutes had to be deep enough to form cutting edges at the 0.012 in. radius tip they were unnecessarily deep along the rest of the cutter and weakened it unduly. This cutter did not in fact have a longer life or cut any better than the much simpler "D" bit. What was obviously wanted was a spirally fluted cutter but with the flutes of constant depth in relation to the outside diameter of the cutter at every point. To make such a cutter it would be necessary for the blank to have, in addition to its normal spiralling motion, an in and out motion in respect to the grinding wheel, so that flutes should have a constant depth regardless of the diameter of the blank at that point.

The method finally adopted is shown in Fig. 98. The blank, held in an appropriate collet, was first ground to a uniform 10 deg. included angle taper and to a diameter of 0.024 in. at the tip. It was then set up in the spiralling workhead in the usual manner except that the workhead was not clamped to its spigot but left free to rise and fall. The upward movement was controlled and the blank guided by positioning it against an

extension bar screwed into the tooth rest. In this way, as the blank was turned, it not only moved back and forth, but rose and fell, its upper surface always remaining at a constant distance from the grinding wheel.

The grinding operation is shown in Fig. 99. Because the flute was very shallow, about 0.010 in. deep, it was nicked out with the corner of a saucer wheel which had been dressed to a sharp edge. The flutes were not very long, about $^{3}/_{16}$ in. because in this instance the cutter was not required to cut more than $^{1}/_{8}$ in. deep. Backing-off was performed at precisely the same setting except that the saucer wheel was replaced by a disc wheel with its axis parallel to that of the cutter. In both cases of course the depth of cut was controlled by moving the wheelhead up and down under control of its micrometer screws. The last operation was the most tricky of all and that was to put a 0.012 in. radius ball nose on the point of the cutter. The set-up was exactly the same as that for larger cutters, first centring the axes of the workhead and rotating base by means of centring pins and then setting the cutter with its tip 0.012 in. from the axis of rotating. Here the setting micrometer was useful, one might almost say essential, because for such fine work setting by eye is not good enough, at least with the writer's eyes it is not, and one has to rely on dead setting to micrometer readings and the accuracy of the machine.

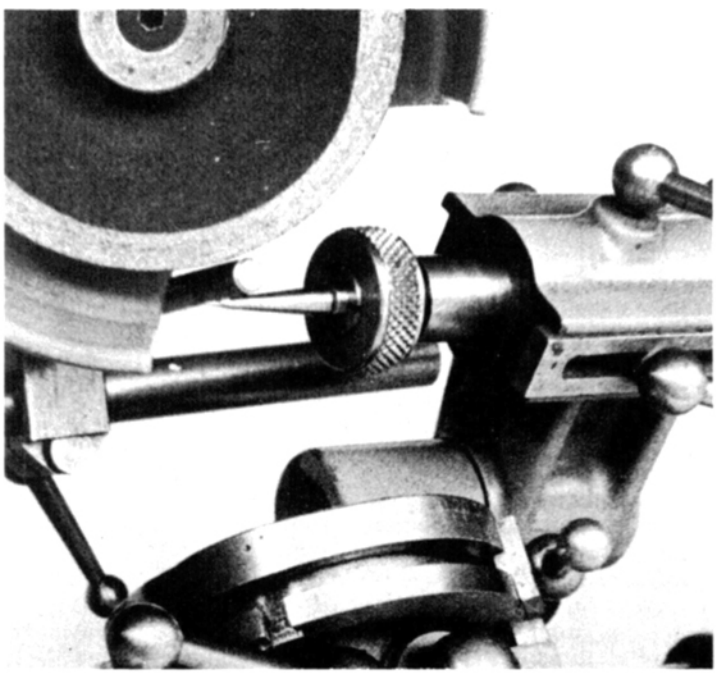


Fig. 99. Grinding a spirally tapered flute.

CHAPTER 15

Other Uses of the Wheelhead

Since the wheelhead with its driving motor form a completely self contained unit it can be removed from its column and used on other machine tools. The high spindle speed, pre-loaded bearings and particularly if it is bored to accept collet chucks make it very suitable for light milling, drilling, engraving and of course grinding operations.

I am indebted to Mr. Hemingway for the photograph in Fig. 100 in which he is using the Quorn wheelhead as a tool-post grinder to finish the cylinder bores of a model Gnome Monosoupape rotary engine. The complete wheel-head together with its driving motor has been transferred to the top-slide of the lathe and held in place by a single extended toolpost bolt. Packing is not necessary because the built-in height adjustment provides a ready and accurate means of bringing the axis of the grinding spindle to centre height. The top-slide is set to an angle of 6 deg. and used to control the fine feed of the grinding wheel towards the work. 6 deg. is roughly equivalent to an inclination of 1 in 10 so that each thou movement of the top-slide fore and aft also corresponds to one tenth of a thou movement in and out.

The only comment that I have on this set-up is that the grinding wheel is rather large in relation to the size of the hole being ground. This gives a very wide arc of contact and even if a soft wheel is used hinders its free cutting. For internal grinding the wheel should not be more than three-quarters of the hole diameter and preferably less. The second point is that the necessarily very small internal grinding wheel is still being driven at a speed appropriate to a much larger cup wheel. Actually the A13 angular contact bearings are, as previously mentioned, rated for a maximum of 15,000 r.p.m. and the spindle can be quite safely driven at this speed by temporarily fitting a larger pulley, up to 7½ in. dia., to the motor spindle. For this sort of improvisation, as also mentioned earlier, the writer favours wooden pulleys as they are light, cheap and give an even better belt grip than metal pulleys. But *please, please,* remember to replace the normal motor pulley before you go back to grinding with a 4 in. cup wheel! If the machine were sold commercially it would have to be fitted with guards which made such tricks impossible, so remember it is a trick but quite safe if you take adequate precautions.

Another use to which the wheelhead of the Quorn can be put is to convert a milling, planing or shaping machine into a temporary surface grinder. In Fig. 101 a 1¼ in. dia. snout has been fitted on the spindle nose of a Dore-Westbury light vertical milling machine and the entire Quorn wheel head clamped to it. The milling machine spindle must of course be locked against rotation and this is done by putting only one of the pins of

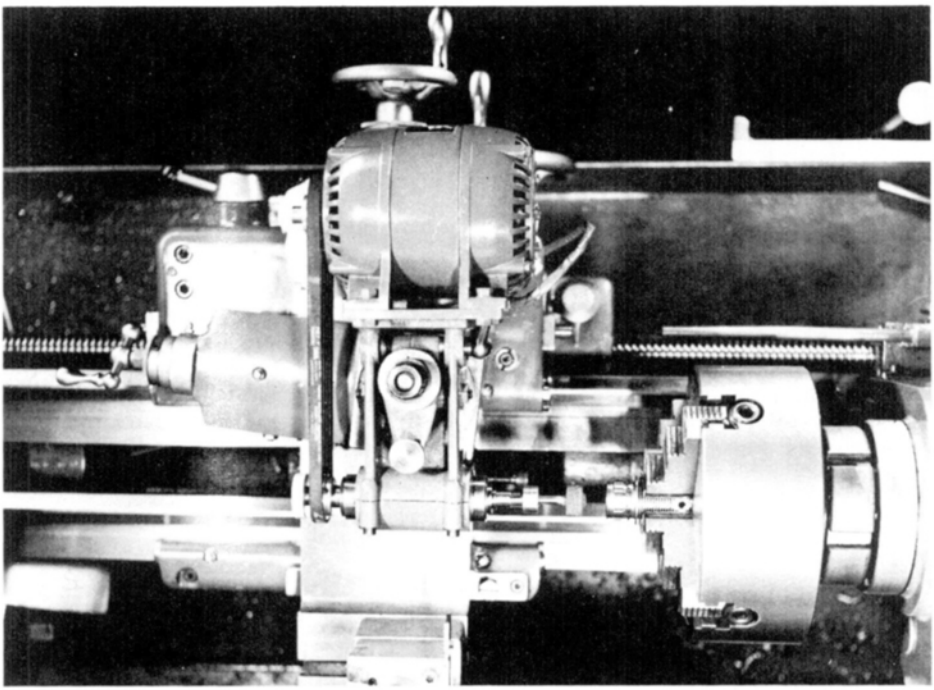


Fig. 100. Internal grinding (Photo Neil Hemingway).

the orbital back gear in the low speed position. This does not, however, remove all backlash so it is also necessary to bias the locked spindle towards a single position by a strong spring, rubber band or weight. Height adjustment and depth of cut can be set either by the milling machine's own height adjustment or the wheel head height adjustment or a combination of both.

In the absence of a magnetic chuck, which is a rather expensive luxury unless one is going to do a lot of surface grinding, the writer has found that double sided "Sellotape" gives excellent results in surface grinding although it is not so successful in turning. This no doubt is because in surface grinding the pressure of the wheel is mainly towards the work and so tends to keep it firmly in place.

In turning, Sellotape is not successful as even with the lightest possible cuts there is a tendency for the tool to catch the edge of the work and tweak it out of contact with the adhesive film.

To get the best out of this rather improbable set-up, shown in close-up in Fig. 102, it is necessary after everything has been fixed in place to dress the periphery of the wheel so that it is exactly co-planar with the ways of the milling machine table, otherwise it will leave "foot marks" on the work. This can be readily accomplished by mounting the dressing diamond in a "V" block or

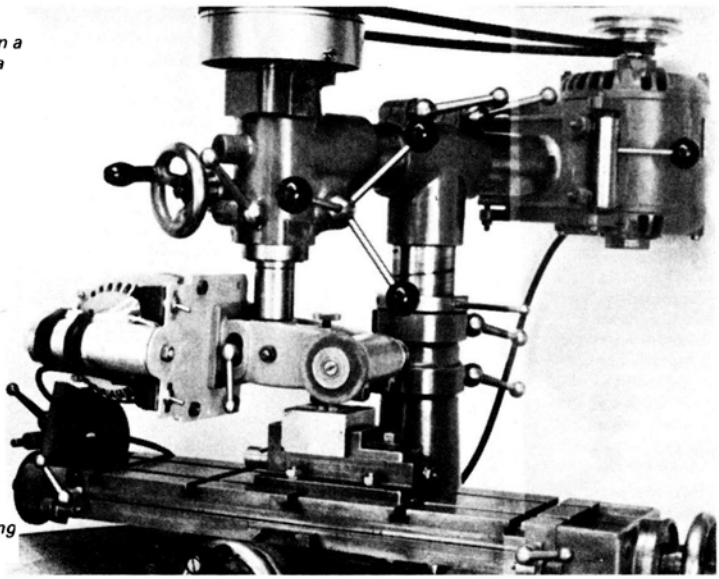
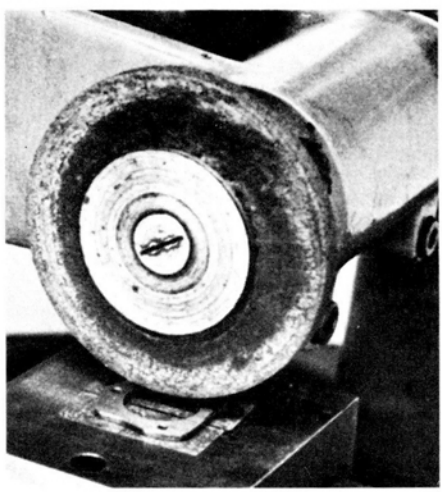


Fig. 101. Using the Quorn wheelhead on a milling machine as a surface grinder.

Below, surface grinding work secured by adhesive tape.

machine vice clamped to the table, again taking the precaution to have a trailing angle and to take light cuts. The block on which the work is going to be mounted, which may be any metal, should then have its face surface ground in position and not of course be disturbed until the job is finished. The work itself may now be stuck to it with a pretty fair assurance that it will be flat and parallel after grinding. Other adhesives may be used, clock makers traditionally use shellac, "Locquic" sets almost instantly and has a surprising tensile strength–almost too much when it comes to removing the work–and the latex based "impact" adhesives can be used if time is allowed for them to dry.

Of course it cannot be pretended that this is more than a "lash-up" and even with care cannot be expected to turn out the same work that would be done on a regular surface grinder. But for the odd job, say the locomotive expansion link which has warped in hardening, it is extremely useful to be able to grind it true again at least to the limits of the ground flat stock from which it was originally made.



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